Shaping an Integrative Front End of Innovation (FEI) in a Design Science Approach

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"Once you were a child. Once you knew what inquiry was for. There was a time when you asked questions because you wanted answers, and were glad when you had found them. Become that child again: even now."

C.S. Lewis, The Great Divorce

"Music does not influence research work, but both are nourished by the same sort of longing, and they complement each other in the satisfaction they offer."

Albert Einstein

I would like to dedicate this thesis to my wise younger brother, his mere presence reminds me of what matters in life, thanks for always being there when I needed you. Moreover, I also dedicate this work to my mother for her love, endless support, encouragement and sacrifices.

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Abstract

The Front End of Innovation (FEI) has a vital role in influencing the development and commercialization of new products and services. This initial phase of the innovation process is acknowledged as an important driver of positive results for new products and for the success of businesses. The FEI is a multidisciplinary area that includes a variety of activities, such as opportunity issues and ideation, analysis regarding technical feasibility, market research, financial viability analysis, business model development, and business plan preparation. Due to the number and variety of FEI responsibilities, this phase entails a considerable level of complexity and crucial decisions. This fact is reflected in the literature, where one finds a variety of FEI approaches and works, seldom overlapping, and consequently hampering the development of a common reference model and language for the FEI. This research aimed at putting forward a Front End of Innovation Integrative Ontology (FEI^2O) as a comprehensive knowledge representation of the FEI. The FEI^2O is a domain model as it explicitly provides a description of a domain regarding: concepts, properties and relations of concepts. Moreover, it defines a common vocabulary and a shared understanding. Therefore, the FEI^2O offers a consistent contribution to the FEI. The present research follows a multi-disciplinary methodological approach. It employs a combination of qualitative and quantitative methodologies, having a so-called mixed approach. This study adopts the Design Science due to the nature of the FEI and the proposed research problem, which addresses the development of a comprehensive and integrative knowledge representation of the Front End of Innovation. The research frameworks from Hevner et al. (2004) and March & Smith (1995) shaped the definition of the research activities and outputs and the 101 Ontology Development Methodology (Noy and McGuinness 2001) provided the seven steps to develop the ontology, followed by a two-phase evaluation approach. The FEI Integrative Ontology (FEI^2O) builds on a) FEI related literature; b) existing ontologies; c) refinement and elicitation of the artefact with domain experts and, d) a two-phase evaluation approach. The global evaluation calculated by an Attribute Agreement Analysis reached an 87.10% of approval and at a sub-ontology level

the scores were: for the High-Level 85.00%; for the FEI Purpose 80.00%; for the Portfolio Planning & Management 90.00%; for the FEI Stage 92.50%; for the FEI Agile 82.50%; and, for the FEI Actors 92.50%. Furthermore, the evaluation of competence questions demonstrated that all questions were answered by the ontology. The results of the ontology evaluation indicate that the FEI^{2}O fulfils its purpose. This is enough evidence to claim the validation of the work. Moreover, the usefulness of the model was analysed considering the instantiation of two application cases. The overarching benefit of the ontology is the proposition of a comprehensive and integrative knowledge representation of the Front End of Innovation, which enables several by-products, namely: a comprehensive tool and a supporting model to address the FEI by means of an FEI^{2}O Canvas; and, a novel approach to look at Entrepreneurship Education.

Keywords. Front End of Innovation; Entrepreneurship; Ontology; Knowledge Representation; Design Science.

Resumo

O Front End da Inovação (FEI) tem um papel vital ao influenciar o desenvolvimento e comercialização de novos produtos e serviços. Esta fase inicial do processo de inovação é reconhecida como um importante impulsionador de resultados positivos para novos produtos e para o sucesso de negócios. O FEI é uma área multidisciplinar e é responsável por diversas atividades, por exemplo, questões referentes à oportunidade e ideação, análises referentes à viabilidade técnica, pesquisas de mercado, análise de viabilidade financeira, desenvolvimento de modelos de négocios e preparação de planos de negócios. Devido ao número e variedade das responsabilidades do FEI, esta fase abriga um nível considerável de complexidade e decisões críticas. Este fato é refletido na literatura, com uma variedade de abordagens e trabalhos para o FEI, os quais poucas vezes se sobropõem, consequentemente, dificultando o desenvolvimento de um modelo de referência e linguagem comum para o FEI. Portanto, esta pesquisa objetivou propor uma Ontologia Integradora para o Front End da Inovação (FEI^{2}O), como uma representação abrangente de conhecimentos do FEI. O FEI^{2}O é um modelo de domínio, pois explicitamente proporciona a descrição de um domínio em relação a conceitos, propriedades e relações de conceitos. Além disso, o modelo define um vocabulário comum e um entendimento partilhado. Desta forma, o FEI^{2}O oferece uma consistente contribuição para o FEI. A presente pesquisa segue uma abordagem metodológica multi-disciplinar. Consequentemente, emprega uma combinação de metodologia qualitativa e quantitativa, tendo uma abordagem denominada mista. Este estudo adota o Design Science como paradigma de pesquisa devido à natureza do FEI e o problema de pesquisa proposto, o qual aborda o desenvolvimento de uma representação do conhecimento abrangente e integradora do Front End da Inovação. As molduras teóricas das pesquisas de Hevner et al. (2004) e March & Smith (1995) modelaram a definição das atividades e resultados da pesquisa, e, a Metodologia de Desenvolvimento de Ontologia 101 (Noy and McGuinness 2001) proporcionou os setes passos para desenvolver a ontologia, seguido por um processo de avaliação composto por duas fases. A Ontologia Integradora do FEI (FEI^{2}O) vale-se da a) Literatura relacionada ao FEI; b)

Ontologias existentes; c) Refinamento e elicitação do artefacto com especialistas do campo; e, d) Uma fase de avaliação sub-dividida em duas sub-fases. A avaliação global foi calculada por meio do uso de um Método de Análise de Concordância, que alcançou 87.10% de aprovação e em termos das sub-ontologias os scores foram: para a High-Level 85.00%; para a FEI Purpose 80.00%; para a Portfolio Planning & Management 90.00%; para o FEI Stage 92.50%; para o FEI Agile 82.50%; e, para o FEI Actors 92.50%. Adicionalmente, a avaliação das questões de competência demonstrou que todas as questões foram respondidas pela ontologia. Os resultados de avaliação da ontologia indicam que o FEI^{2}O cumpre seu propósito. Essas são evidências suficientes para reivindicar a validação do trabalho. Além disso, a utilidade do modelo foi analisada considerando a instanciação de dois casos de aplicação. O benefício global da ontologia é a proposição de uma abrangente e integradora representação de conhecimento do Front End da Inovação, propiciando diversos sub-produtos, nomeadamente: uma ferramenta abrangente e modelo de suporte para abordar o FEI por meio de um FEI^{2}O Canvas; e, uma abordagem inovadora para abordar o ensino do empreendedorismo.

Palavras-chave. Front End da Inovação; Empreendedorismo; Ontologia; Representação do Conhecimento; Design Science.

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List of Abbreviations and Acronyms

AI	Artificial Intelligence
AO	Agile Ontology
BS	Business Strategy
BMD	Business Model Development
BMO	Business Model Ontology
CO	Context Ontology
COIN	Collaborative Innovation Network Ontology
CQ	Competence Questions
CD	Concept Development
CSF	Critical Success Factors
CULT	Culture
DS	Design Science
EO	Enterprise Ontology
EST	Enabling Sciences and Technologies
FEI	Front End of Innovation
FEI^2O	Front End of Innovation Integrative Ontology
FFE	Fuzzy Front End
FEF	Front End Fuzziness
FPP	Feasibility and Project Planning
IE	Idea Enrichment
IG	Idea Generation
IM	Innovation Management
IS	Idea Selection
LD	Leadership
LU	Lead User
MP	Market Pull

MOT	Strategic Management of Technology
NCD	New Concept Development
NPD	New Product Development
OA	Opportunity Analysis
OC	Organizational Capabilities
OECD	Organisation for Economic Co-operation and Development
OI	Opportunity Identification
ORS	Ontology Requirements Specification
OW	Outside World
P0	Phase Zero
P1	Phase one
PCD	Product Concept Development
PDMA	Product Development Management Association
PDO	Product Development Organisation
POI	Preliminary Opportunity Identification
PP0	Pre-Phase Zero
PP&M	Portfolio Planning & Management
P&PS	Product & Portfolio Strategy
R&D	Research and Development
SME	Small and Medium Enterprise
TM	Technology Management
TPM	Technology Product Market
TRM	Technology Roadmapping
TP	Technology Push
TTO	Technology Transfer Office

Chapter 1 Introduction

The notion of a *fuzzy* part of the innovation process (Du Preez & Louw, 2008; Koen et al., 2002; Trotter & Vaughan, 2012; Tidd, Bessant & Pavit, 2008) depicts a phase with high-levels of complexity, for instance, the environment, the individual and the organisation (Reid & De Brentani, 2004). Consequently, it comprises vital decision-making processes and management efforts. The *Fuzzy* Front End, or the so-called Front End of Innovation, has peculiarities and complexities – understood as challenges – to be overcome in order to achieve a successful New Concept and Business Model Development.

Even though the Front End of Innovation is an important driver of positive outcomes, there is a lack of a comprehensive and integrative approach for this knowledge domain. A FEI ontology can be a valuable addition to the field, as it carries the potential to facilitate the balance between structure and flexibility. A promising approach to support the enrichment of the FEI foundation is the use of ontology, as a comprehensive knowledge representation. The effective modelling power of ontologies is useful to represent the nature of the Front End of Innovation. Insofar, there are few ontologies to the beginning of the innovation process, the literature review highlights two works concerning the ideation phase: "Innovation and Ontologies: Structuring the Early Stages of Innovation Management" by Bullinger (2008) and "An Idea Ontology for Innovation Management" (Riedl et al., 2009). These works provide significant contributions to the field, however, with a focus on the ideation.

A comprehensive and integrative model is advantageous to increase the effectiveness of the management of the FEI and to foster further research. The literature emphasises the criticality of the FEI for innovation outcomes (Wagner, 2012), as this phase holds a potential to foster the coordinated process of product concept development. However, the FEI is also recognised as the weakest phase of the innovation process (Khurana & Rosenthal, 1997; Koen et al., 2002).

The literature review presented in Section 2.6 shows that increasing attention has been paid to the FEI in recent years, but it only became a consistently increasing trend in the field from 2006. These FEI research are valuable to advance the knowledge, but the literature review, developed by this thesis, expose gaps in this knowledge domain, which are addressed in Sections 2.5.6 and 6.1. Moreover, the FEI literature presents a variety of FEI approaches and works, given the level of complexity, activities and crucial decisions in this phase. This variety of approaches seldom overlap, consequently hindering the enrichment of a common reference model and language for the FEI. Starting from these issues this research developed an FEI Integrative Ontology (FEI^2O). The FEI^2O organises the body of knowledge around the FEI, making it useful as an effective basis to organise FEI processes as well as a framework relevant for future FEI research.

1.1 General Context

The innovation process, responsible for the development of innovative products or services, may be organised into three parts, namely *Fuzzy* Front End (FFE) or Front End of Innovation, New Product Development (NPD), and Commercialisation (Koen et al., 2002). The innovation process starts with the *Fuzzy* Front End, which is known as fuzzy since this phase involves inaccurate processes and *ad hoc* decisions (Montoya-Weiss & O´Driscoll, 2000).

The FEI process comprises a broad range of activities and responsibilities concerning several topics, for instance: ideation; opportunity identification and analysis; organisational capabilities and structuring; product and portfolio strategy; feasibility analysis; project planning; global trends analysis; concept definition; customer and competitor analysis, and even business model development.

The importance of FEI relies on the fact that Front-end processes are capable of influencing product performance more than New Product Development processes, strategy or champions[1]

[1] Champions refers to the role that someone performs to bring awareness of opportunities to the organisation.

(Markham, 2013). In fact, other studies stress the importance of FEI activities and organisational attributes (Giles & Cormican, 2014; Koen et al., 2014a, 2014b).

1.2 Research Problem

Currently, the technological landscape enables a wide variety of opportunities for entrepreneurs and companies to innovate, such as The Web of Things, *Industrie 4.0*[2], Cloud-based data, Nanotechnologies and Nanoscience, Material Sciences, the perspectives and developments of Artificial Intelligence, Robotic Innovations, Life Sciences and Biotechnologies. Nonetheless, to be fruitful an innovation needs to be more than an answer to an opportunity, it needs to be economically viable, technically feasible, and as an expected result, successful in the market (Mueller & Thoring, 2012).

Academic research about the innovation process helps entrepreneurs and organisations to take advantage of the opportunity landscape by giving them tools to minimise the risks of innovation costs, contributing to a reduced innovation time to market and balancing the increasing technological complexity. Despite the FEI relevance to successful commercialisation and even to the overall business success, previous research has not addressed an ontological approach to the contiguous disciplines of Research and Development (R&D) and Technology Management (TM) for the FEI (Bullinger, 2008).

Notably, technological risks and market uncertainties bring difficulties to the decision-making process in organisations. Nonetheless, their challenges lie in choosing the technologies to develop as well as which customer's decision to accept (Bohlmann, Spanjol, Qualls, & Rosa, 2013). To help organisations to deal with this scenario a representation of the dynamic interaction of market and technology in the beginning of the innovation process would be beneficial. However, there is an absence of approaches concerning the interface of Technology Push (TP) and Market Pull (MP), moreover few models are addressing the connection between technology push and market pull (Maier, Hofmann & Brem, 2016).

[2] *Industrie* 4.0 refers to the name coined by the German Government to a strategic initiative to establish this country as a lead market and provider of advanced manufacturing solutions.

Entrepreneurs and firms face difficulties to manage innovation. Both incremental and radical innovations require attention to overcome the risks that are associated with new products and services. Research has highlighted the difficulty that businesses face in developing commercially successful, innovative products and services. There are remarkable statistics concerning this scenario, 80-90% of new product launches fail, but 80% of business leaders believe in the importance of innovation, and as much as 65% are dissatisfied with their ability to innovate (Trotter & Vaughan, 2012).

Furthermore, concerning the FEI theory, there is relatively little research on the management of this phase in the innovation process (Robbins & O'Gorman, 2015). A recent study shows that current innovation models are not linked to the insights that can be gleaned from significant theories, including pertinent theories of creativity, knowledge, and design science (Gregor & Hevner, 2015).

Pereira, Ferreira, & Lopes (2017) suggest that this topic has received greater attention in recent years both regarding depth and number of publications. However, there are still pending gaps in the literature. For instance:

- Eliens & Xavier (2015) highlight the high number of publications related to tools and methodologies. Although these works bring some insights to the field, most of the contributions address the effect that a specific tool has on a particular FEI process. As a result, many publications do not generate a substantial amount of knowledge for the FEI research field as a whole. There is a lack of contributions regarding the so-called process activity models (mapping of the entire FEI process).
- Recent work, regarding the applicability of modern approaches in the FEI, by Gonzáles (2014), uncovered insufficient findings for the use of agile project management.

Other issues related to the FEI concerns, for instance, a variety of approaches given to this knowledge domain. For example, Pereira et al. (2017) indicate the multitude of expressions used to address the earliest stage of the innovation process, namely: Early Phase of Innovation, Early Stage of Innovation, Pre-development Innovation, Front End of Innovation and Fuzzy Front End. Furthermore, a diversity of models is also evident. Some authors address the FEI from different perspectives due to its multidisciplinary nature. However, this diversity of

models poses challenges, on deciding which approach to use and which concept definitions to adopt. The term opportunity exemplifies this diversity; Table 1-1 shows a comparative analysis of the term opportunity according to some traditional FEI References.

Apart from Cooper (2001, 2008), other traditional FEI works emphasise the opportunity concept with a clear distinction between opportunity and idea.

Table 1-1 Analysis of Main FEI Reference Models focused on Opportunity

Opportunity activities	**Main responsibilities**
Opportunity Identification and Analysis Koen et al. (2002)	Identification and analysis of opportunities. Assessment and definition of the customer, market and/or technology. Alignment of the opportunity with the business strategy and culture.
Scoping Idea Cooper (2001, 2008)	Preliminary market assessment. Preliminary technical assessment. Preliminary business & financial assessment. Recommendations & plans for building the business case.
Pre-phase zero Khurana and Rosenthal (1997, 1998)	It is responsible for a preliminary opportunity identification, together with a market and technology analysis. It responds to the identification of customer needs, market segments, competitive landscape, and business prospects. It demands a clear understanding of the existing business and technology plans. It is responsible for coping with the product and portfolio strategy.
Boundary Interface Gatekeeping Interface and Information Flows *Reid and De Brentani (2004) De Brentani and Reid (2012)*	The Boundary Interface comprises of an inward flow of information from the environment to the individual. It consists of the analysis of unstructured problems and location of identified opportunities. Gatekeeping Interface and Information Flows represent the point at which information flows from the environment, and the evaluation process starts according to the relevance of the information to the organisation.

This overview is by no means comprehensive; nonetheless, it does list vital and seminal contributions to the FEI. The most frequently cited models in the literature are the Stage-Gate Process (Cooper, 2008), the Three Phase Front End Model (Khurana and Rosenthal, 1997) and the New Concept Development Model (Koen et al., 2002), according to Gaubinger and Rabl (2013). Due to their relevance, they were used as the starting point to narrow the analysis of

the opportunity concept. The next chapter gives a more detailed analysis of this main FEI models and their proposed activities depicting their coverage and gaps.

This research aims to promote a holistic and comprehensive understanding of the Front End of Innovation, as the "front-end performance favourably and independently impacts overall product success, time to market, market penetration, and financial performance" (Markham, 2013, p. 77).

1.3 Research Question

Inspired by the research problem, this research asks the following questions:

1) How can we build a comprehensive knowledge representation of the Front End of Innovation?
   a) Which components would this FEI knowledge representation comprise?
   b) Which would be the boundaries of this knowledge representation?

1.4 Motivation

Due to the number and variety of FEI responsibilities, this vital part of the innovation process entails multidisciplinary activities and crucial decisions. This scenario has led scholars to suggest that the nature of FEI is experimental and chaotic comprising unstructured and *Ad-Hoc* decisions (Koen et al., 2002; Montoya-Weiss & O'Driscoll, 2000). This fact is reflected in the literature with a variety of FEI approaches and studies, wherein the most critical concerns lie in the proposition of different models that seldom overlap.

This variety of approaches hampers the development of a common reference model and language for the FEI. As such, this research aimed at overcoming this issue by proposing an FEI Ontology framed as "a comprehensive knowledge model which enables the developer to practice a "higher" level of re-use of knowledge" (Wang & Chan, 2001). For this purpose, this work makes use of the Design Science as a conceptual basis for engineering an Integrative Ontology for the Front End of Innovation.

Former studies have not addressed an ontological approach to the contiguous disciplines of R&D and Technology Management (TM) for the FEI (Bullinger, 2008). TM is a multidisciplinary field that has been rapidly expanding over the last two decades (Lee, 2015). It links the field of engineering, science and management by planning and developing the implementation of technological capabilities to shape and fulfil the strategic and operational organisational objectives (US Research National Council, 1987). Thus, TM comprehends the stages of the technology development and pre-development activities (Specht, 2002 apud Brem and Voigt, 2009).

Activities that take place in the FEI may be well suitable for offering a basis to the company and entrepreneurs to understand opportunities and make up-to-date and well-structured new concepts. Therefore, the overall motivation of this thesis is to design a comprehensive knowledge representation of the FEI.

1.5 Research Objectives

The main objective of this thesis is to develop a comprehensive knowledge representation modelling the dynamic relation of FEI concepts. To meet the general objective of this work secondary objectives were defined.

a) Identify the tools of knowledge representation that contribute to the task of modelling FEI Concepts and its relations;
b) Define which method of knowledge representation will be used;
c) Propose an integrative and comprehensive model of the FEI; considering the identified components and the established boundaries for this knowledge representation;
d) Explore and evaluate the proposed model through an evaluation process with domain experts.

1.6 Thesis Contributions

An ontology is a knowledge representation with a high degree of flexibility, which enables it to be easily adapted. The application and benefits of ontologies are not restricted to the realm of Artificial Intelligence; it is also found at a corporate level and educational contexts.

The present work provided a formal FEI Reference Model built upon existing literature and concepts and relations elicitations with domain experts and end-users. The Front End of Innovation Integrative Ontology (FEI^2O) enables several contributions. The summarised envisioned benefits of this knowledge representation comprise:

- A basis for guiding entrepreneurs in developing innovative concepts.
- A foundation for further studies in this knowledge domain.
- The proposed sub-ontologies may unfold guidelines and management tools to FEI process and FEI projects.
- A comprehensive conceptual FEI model helpful for contributing to organise curriculum activities.
- A holistic teaching perspective for the FEI.
- The further development of the FEI^2O Canvas can unfold a methodological roadmap for students, entrepreneurs, innovation practitioners and managers.
- A pedagogical tool to support learning activities and the development of innovation projects in the classroom.

The FEI^2O offers a comprehensive approach to the FEI with a variety and usefulness of applications, the by-products of this work need to be further developed, as the period time of this thesis does not allow their development. The overarching contribution of the FEI^2O is to offer comprehensive and integrative knowledge representation to the process of developing a New Concept. Chapter 6 presents a more detailed discussion of the FEI^2O applications.

1.7 Methodological Approach

The research methodology follows a mixed approach. It makes use of a multi-disciplinary scheme; by employing a combination of qualitative and quantitative research methodologies. The qualitative research enables an in-depth analysis of any given phenomena while the quantitative approach assesses the ontology, hence validating the work.

The research problem addresses a major problem faced by companies when they need to overcome the challenge of innovation. Therefore, the strategy of this study is to use the Design Science (DS) approach. In this sense, it is worth to consider that it has been proved that DS is helpful for building ontologies (Osterwalder, 2004; Bullinger, 2008). This view alongside with engineering planning deal with complex systems of complex environments, as such they benefit from the science of the artificial (Simon, 1997). In addition, other authors also found DS helpful to build ontologies (Barradas, 2015; Bullinger, 2008; Osterwalder, 2004).

The applicability of the Design Science as a means of engineering an ontology helps to answer this thesis Research Questions. Consequently, the research problem arose from an integrative literature review, which also exposes gaps in the knowledge domain. It served to characterise the domain of the ontology using the Ontology Requirement Specifications. Furthermore, it borrows from March and Smith (1995) the concepts of build and evaluate, but does not completely address the theorise and justify as corroborated by the works of Barradas (2015), Bullinger (2008) and Osterwalder (2004). These concepts were applied considering an integration of two Design Science Research Frameworks (Hevner, March, Park, & Ram, 2004; March & Smith, 1995).

The evaluation process of the ontology concerns two stages: the first an exploratory phase, to foster concept elicitation, revision and expansion of the ontology; followed by the second phase to validate the work. The first consisted of individual interviews while the second relied on the use of a focus group both of which considered the participation of domain experts for the evaluation procedures.

Finally, it was analysed the utility of the FEI^{2}O through the instantiation of the Jersey Square – a Lean Start-up Case Study and the mobLee a real case from a Brazilian Start-up.

1.8 Thesis summary

The thesis consists of seven chapters, which are briefly described in the following paragraphs.

Chapter 2 briefly presents an introduction to innovation and innovation management while given an in-depth analysis of the Front End of Innovation. This emphasis addresses topics such as Entrepreneurship; Sources of Opportunity; FEI Models and an Integrative Literature Review. This chapter further discusses the topic of Technology Management and gives an overview of Methodologies to develop ontologies.

Chapter 3 concerns the Research Methodology and presents: Integrative Literature Review; Research Methodological Procedures; Ontology Development: Ontology Evaluation Methodological Procedures and Conclusions. This chapter addresses methodological issues related to the research procedures. Thus, it answers the questions identified in the previous chapters.

Chapter 4 introduces the Front End of Innovation Integrative Ontology – FEI^{2}O with its subset of sub-ontologies: The FEI Purpose; FEI Portfolio Planning & Management; FEI Agile NCD; FEI Stages and FEI Actors. Moreover, the chapter presents the High-Level sub-ontology that depicts the interdomain key relationships of the core concepts.

Chapter 5 addresses the ontology evaluation process and is divided into four sections. The first addresses the Exploratory Phase of the ontology evaluation. The second reports the Validation Phase. The third regards the assessment of the Competence Questions and is followed by a summary of the chapter.

Chapter 6 regards the Implications of the work. It addresses the FEI^{2}O and the main FEI reference models. Moreover, it explores the potentiality of the FEI^{2}O Canvas with its future developments in Educational and Business Context. And, the instantiation of the model is also dealt within this chapter considering two cases. This chapter also presents the applicability of the artefact as a base for future research developments. It closes with generalisations, results limitations and conclusions are presented.

Chapter 7 presents the final considerations, main thesis contributions, research limitations, recommendations for managers and directions for future work.

Chapter 2 Managing the Front End of Innovation

2.1 Introduction

Companies have frequently been directing efforts in their Innovation Management processes. However, they have a propensity to overlook the so-called Front End of Innovation (FEI) or the beginning of the innovation process. The FEI refers to doing the "right things" in innovation (Markham, 2016) and plays a vital role at increasing the probability of success of the concepts developed for commercialisation. After the FEI, there is the Product Development, and finally, the commercialisation phase. These three phases are often used to represent how the innovation process is organised.

This chapter presents a brief overview of the innovation concept in the next section, which is followed by the innovation management (Section 2.3). Moreover, Section 2.4 addresses the Front End of Innovation; comprising the topics of Entrepreneurship and Sources of Opportunity to innovate. Furthermore, Section 2.5 provides an analysis of important works for the FEI while Section 2.6 address an Integrative Literature Review. Additionally, Section 2.7 focuses on Technology Management and the analysis of the use of Technology Roadmapping, Lead User and Technology-Product -Market. Lastly, Section 2.8 presents the topic Ontologies and Methodologies used to develop ontologies.

2.2 Innovation

Innovation is a broad field and can be regarded as Product Innovation, Organisational Innovation, Marketing Innovation and Process Innovation (OECD, 2005). Some of the innovation characteristics are highlighted by the Oslo Manual (OECD, 2005), they are:

a) innovation is associated with uncertainty;
b) innovation demands investment;
c) innovation produces benefits for other firms besides the one who innovated;
d) innovation requires the use of knowledge or even new use or a combination of existent knowledge; and
e) innovation seeks to improve a company's performance through competitive advantage.

Innovation is a critical issue for organisations and countries. In fact, technological Innovation has a disruptive character that promotes differentiation for organisations, which may enable them to have a distinctive position in the competitive market (Schumpeter, 1988). Furthermore, technology is a broad concept that represents a means to accomplish a certain end (Eckhardt, 2013).

Studies suggest that innovation may lead organisations to a prominent position (Banbury and Michell, 1995). In this context, new products play an important role, as they may generate new revenues and new markets (Tidd et al., 2008).

Innovation stems from ideas that are the result of a creative or rational thinking process; this process may have the involvement of several actors, such as employees, customers, suppliers or universities organised as individuals or groups (Boeddrich, 2004). Moreover, innovation is a concept that depicts not only something that is new but also that is economically viable, technically feasible and expected to be successful in the market (Mueller & Thoring, 2012).

It is possible to identify innovation regarding the degree of its impact, for instance, incremental and radical (Tidd et al., 2008) or it can be understood as continuous and discontinuous (Veryzer, 1998). Nonetheless, innovation may be seen as sustainable or disruptive innovation (Christensen, 2001). "Definitions of radical innovation generally allude to aspects related to high market and technological uncertainty, new market creation, new capabilities in the innovating firm, and the possibility that such innovations might cannibalize a firm's prior business model"(Robbins & O'Gorman, 2015, p. 77).

In sum, innovation management plays, a key role in companies seeking to find innovative products and business opportunities, as such the next section explores these in more detail.

2.3 Innovation Management

Entrepreneurs and companies face a challenge when it comes to managing innovation. Both incremental and radical innovations require attention to overcome the risks that are associated with new products and services.

Innovation almost never fails due to a lack of creativity. It is the lack of discipline that plays a major influence on innovation failure (Keeley, Walters, Pikkel & Quinn, 2013). In this regard, one aspect of the Innovation Management (IM) is on how to find the solution that best suits the problem of turning ideas into a successful reality. It is expected that organisations will always strive to do it in the most feasible way (Bessant, 2003). According to Boeddrich (2004), there is a need for procedures that are methodical, systematic and structured in the initial phase of the innovation process, in order to avoid detrimental effects on the innovation management. Figure 2-1 exemplifies how innovation management is a broad field and how it relates to R&D Management and Technology Management.

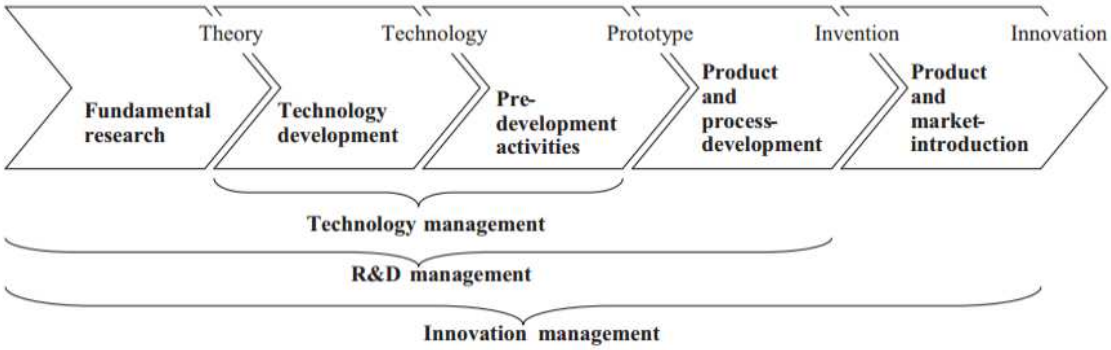

Figure 2-1 Classification of technology, R&D and innovation management (Specht, 2002) apud (Bren and Voigt, 2009)

Scholars, as well as business practitioners, acknowledge the high importance of the innovation management process, namely considering the vital role played by the earliest stage, which is responsible for identifying business opportunities as well as the best choices for their accomplishment (Stevanović, Marjanović, & Štorga, 2016). Research shows that FEI optimization and improvement lead organisations to positive results by increasing chances of

innovation development (Boeddrich, 2004; Koen et al., 2014b; Markham, 2013; Stevens & Burley, 2004; Verworn, Herstatt, & Nagahira, 2008; Williams, Kochhar, & Tennant, 2007).

Therefore, the next section focuses on characterising the FEI; presenting its relationship with entrepreneurship; identifying the Main FEI Reference Models, their contributions and knowledge gaps; and, an integrative literature review of this domain knowledge.

2.4 Front End of Innovation

The Fuzzy Front End (FFE) regards the earliest stage of the New Product Development - NPD process. This term was made popular by Smith and Reinertsen (1991) (Khurana and Rosenthal, 1997; Reid and De Brentani, 2004; Verworn et al., 2008), but a more recent nomenclature, coined by Koen et al. (2002) is the Front End of Innovation, hence dissociating the notion of a fuzzy or unmanageable phase. The FEI process is described as the work that is done toward developing a product before this project enters the formal NPD (Markham, 2013).

The FEI requires attention since it is an important driver of positive results for new products and for the overall success of the business (Kock et al., 2015). Stephen Markham discusses the impact of front-end activities on product performance and highlights that the front-end success is the strongest independent predictor of all of the NPD performance variables. Still, according to Markham (2013), the first stages of the innovation process are the critical phases, because the performance of the FEI impacts product success, time to market, market penetration, and financial performance (Markham, 2013).

This phase is vital for the successs of the innovation process, as the FEI contributes “to increase the value, amount, and success probability of high-profit concepts entering product development and commercialization” (Koen et al. 2002, p. 5). Therefore, a solid comprehension of the activities and decisions comprised in the FEI is an important aspect for entrepreneurs and organisations, in order to obtain competitive advantage (Reid and De Brentani, 2004).

There are differing views concerning the FEI structure. More specifically, some authors highlight significantly different approaches to promote radical or incremental innovations in

NPD projects at the FEI (Reid and De Brentani, 2004). Recent work argues for no significant differences between these two types of innovation (Verworn et al., 2008). Another debate concerns the benefits of adopting a structured versus a non-structured approach for the FEI process. Nonetheless, recent research has shown the benefit of intensive initial planning and the process-oriented approach (Verworn et al., 2008; Markham, 2013). Consequently, it is necessary to consider the size of the company, the decision-making style, the organisational culture and frequency of new products introduction, in order to choose a front-end solution (Khurana and Rosenthal, 1997).

The nature of FEI activities may or may not be sequential. Nonetheless, projects must pass through logical phases of development, even if they must repeat an activity or regress through iterative loops. Therefore, even though activities may be iterative, the project must develop "toward a discernible state of development for it to be accepted into the company's formal development process." (Markham, Ward, Aiman-Smith, & Kingon, 2010, p. 408).

The beggining of the innovation process is not only responsible for opportunity and ideation, but the FEI also entails activities regarding technical feasibility demonstrations, market research, financial viability analysis, business model development, and business plan preparation (Markham et al., 2010). In this context, entrepreneurship plays a key role in the FEI. The next section will address it considering its role in the FEI.

2.4.1 Entrepreneurship

Entrepreneurs who take advantage of change as an opportunity are in fact using innovation as their specific tool (Drucker, 2006). Furthermore, they have high hopes concerning the benefits of innovation. However, studies have shown that companies tend to start the FEI without a clear definition or analysis of the process of how to go from Opportunity Identification to Concept Generation; as a result, the FEI process is often aborted or forced to be restarted (Achiche, Appio, McAloone, & Di Minin, 2013). These difficulties in managing the FEI process may affect the innovation success rates of an enterprise.

An entrepreneur is always searching for change; therefore he/she responds and exploits it as an opportunity (Drucker, 2006). In addition, entrepreneurship is a theme that has received growing

attention in the past few years. For countries, the significant role of entrepreneurship is mostly related to the economic and social development foster by small and medium enterprise (SME). However, regions that share the same level of economic development may not share the same rates of entrepreneurship.

For Timmons & Spinelli (2009, p. 101) “entrepreneurship is a way of thinking, reasoning, and acting that is opportunity obsessed, holistic in approach, and leadership balanced for the purpose of value creation and capture.” Entrepreneurship is intrinsically related to opportunity and an FEI encompasssing definition for this concept is offered by Koen et al. (2002). These authors consider an opportunity as a business or technology gap, identified by an entrepreneur. It exists considering the current situation and an envisioned future to capture competitive advantage, respond to a threat, solve a problem, or relieve a difficulty. Opportunity is different from an idea; the latter represents “the most embryonic form of a new product or service”. It often consists of a high-level view of the solution envisioned for the problem identified by the opportunity (Koen et al. 2002 p. 7).

This work uses the definitions of Opportunity and Idea as provided by Koen et al. (2002) as the NCD Model is a proved and accepted method by the Product Development Management Association (PDMA).

2.4.2 Sources of Opportunity

Opportunities by themselves are not businesses. However, they do represent a feasible set of goods and services that may be generated to future commercialization – at any given point in time (Eckhardt, 2013). Consequently, it is important to look at the possible sources of opportunities as a triggering point to the FEI process. Table 2-1 shows an overview of possible sources of innovation. This table is not exhaustive, as it is not the objective of this thesis to provide an in-depth exploratory analysis of the Opportunity concept but of the Front End of Innovation.

Attention should be given to opportunity, as this is still a concept evolving and receiving growing attention over time. A recent study performed a critical evaluation of the concept “opportunity” considering 210 papers published in leading journals (Davidsson, 2015). The

authors of the study remark that "opportunity" lacks clarity and this fact may be explained due to the vague, varied and even inconsistent definitions of the term.

Sources of opportunities are triggers to innovate and they account for internal and external opportunities. Once again, these sources of opportunities (Table 2.1) are not exhaustive, but they consist of an overview of the reasons to innovate and, as indicated by Drucker (2002), the potential for innovation may be found in more than one area at a time. The opportunity concept received a special emphasis due to the critical role that an opportunity plays to the FEI. Some of the criticism of Davidson (2015) regarding the misconception of opportunity were dealt with in this thesis. The concepts Internal and External Source of Opportunity; Opportunity Recognition and Opportunity Confidence are components of Opportunity, therefore, the concept was considered as a broad conceptualisation by the Front End of Innovation Integrative Ontology (FEI^{2}O).

Table 2-1 Possible Sources of Opportunity to Innovate

Sources of Opportunities according to Drucker (2002)	
The unexpected	It refers to unexpected occurrences, whether they are successful experiences or failures. Unexpected successes and failures are productive sources of innovation opportunities because most businesses dismiss them, disregard them, and even resent them.
The Incongruity[3]	Innovation may start from the incongruity within the logic or rhythm of a process. Moreover, an incongruity between expectations and results can also open up possibilities for innovation, as well as incongruity between economic realities.
Process need	It comes from the exploitation of a process need.
Industry and Market Structure Change	Industry structures can—and often do—change overnight, thus it becomes one source of opportunity.
Demographics	Among the sources of innovation opportunities, demographics may be understood as the most reliable, because demographic events have known lead times. For instance, it enables innovation opportunities by changes in population number — and in their age distribution, education, occupation, and geographic location.

[3] From incongruous, which according to the Cambridge Dictionary (2017) represents the unusual or different from what is around or from what is happening.

Changes in perception	A change in perception does not alter facts. It changes their meaning, and it can be understood as a source of innovation opportunity. Besides, change in mood frequently challenges quantification. This change can be defined, tested and exploited for innovation opportunity.
New Knowledge	Knowledge-based innovations are unique in the time they take, in their casualty rates, and in their predictability along with the challenges they pose to entrepreneurs. To become effective, this type of innovation frequently demands many kinds of knowledge.
Opportunities to innovate according to van Wulfen (2016) can be understood as routes, they are:	
The Idea Route	Considered by the author as an essential activity incorporated in every route to a new offering.
The Technology Route	It starts with the discovery of a new technology.
The Customer Issue Route	The Customer Issue Route represents the identification of an unsolved pain point of the customer.
The Business Challenge Route	It is a route when the business needs to innovate.
Forces generating entrepreneurial opportunities can be understood as drivers of entrepreneurial opportunities, Bikard (2010):	
Technological Evolution	Some researchers have argued that the level of technological maturity greatly impact the number of entrepreneurial opportunities. For instance, exploring fields of young industries as they comprise needs not yet well-defined, therefore presenting more opportunities than established fields.
Organizational Environment	In general, new business opportunities rely on the presence of overlapping suppliers (competitors) and the presence of complementary organisations.
Demand Characteristics	Demand besides being unstable is also never relatively homogeneous: customer preferences are in general diverse enough making available parts of the market underserved.
Institutional Context	The institutional context is a broad topic, examples that illustrate this source of opportunity are changes in policy regime, changes in the law, and changes in intellectual property regulation. These and other possibilities regarding institutional environment can have a dramatic impact on entrepreneurial opportunities.

The next section will address the Main FEI Reference Models. Consequently, it presents the opportunity concepts of these models as well as the other FEI activities.

2.5 Analysis of Main FEI Reference Models

2.5.1 Introduction

FEI activities have a distinctive nature being both experimental and often chaotic. In contrast, the NPD stage is more focused, disciplined and goal-orientated with a well-defined project plan (Gregor & Hevner, 2015; Koen et al., 2002). Montoya-Weiss and O´ Driscoll (2000) refer to the Fuzzy Front End (FEI) as unstructured and *Ad-Hoc*. Despite the "fuzziness" of this stage, the FEI is the foundation for the generation of successful New Product Development (NPD) (Martinsuo & Poskela, 2011).

The FEI is a multidisciplinary field of study. This knowledge domain has received growing attention in recent years. It was found[4] that 26% of articles, from a total of 169, were contributions in terms of a framework, a model, a process, a tool or even a methodology (Pereira et al., 2017). These studies exemplify attempts to develop this knowledge domain. Although recent contributions are highly recommended, there are reference models in seminal works, which focus on the initial stages of the innovation process. Due to their relevance to the field, they are detailed in the following sections.

Four papers are continuously cited in works approaching FEI models and frameworks, as evidenced by the literature review (Table 2-2) and supported by Gaubinger and Rabl (2013).

[4] Section 2.6 presents the complete Integrative Literature Review. This study was published in the Journal of Innovation Management JIM 5, 1 (2017) 22-39.

Table 2-2 FEI Reference works

Work	Authors	Focus
Stage-gate Process	Cooper, R. G.	This work aims at a successful product innovation process, from idea to launch. The first phases represent the FEI and make use of stage-gates.
Three Phase Front End Model	Khurana, A. Rosenthal, S. R.	It is a front-end approach that links business and product strategy with product-specific decisions.
New Concept Development Model	Koen et al.	The aim of the work was to provide methods, tools, and techniques suitable for managing the Front End of Innovation. Furthermore, the authors envisioned the possibility of specifying a vision and a common terminology for FEI.
The Fuzzy Front End of New Product Development for Discontinuous Innovations	Reid, S. E. De Brentani, U.	This study focuses on disruptive innovation. A structure based on the idea of a reversed information flow from the outside world toward the organisation. Individuals who play important roles facilitate this flow. The first interface consists of "boundary interface," followed by the "gatekeeping interface" and concluded by the project interface.

Qualitative research uses category of analysis to prepare, categorize and interpret information. Consequently, Table 2-3 presents the definitions of the concepts adopted to analyse the Main FEI reference models.

Table 2-3 Concept definitions

Concept	Definition
Opportunity	It is when an entrepreneur or organisation recognises a gap whether related to a business or technology issue. This situation exists between the current situation and an envisioned future. Opportunity can be utilised to acquire a competitive advantage, to offer a response to a threat, to solve a problem, or to improve a situation (Koen et al., 2002).
Idea	The most preliminary form of a new product or service. It frequently covers a high-level view of the solution planned for the problem identified by the opportunity (Koen et al., 2002).
Concept	The concept has a precise configuration. It comprises a written and visual description, covering its primary features and customer benefits connected with a broad understanding of the technology needed (Koen et al., 2002).
FEI Foundation	Foundation refers to a basis upon which something stands or is supported (Merriam-Webster, 2017), in this case, it relates to the FEI foundation.
Outside World	It represents things that are not coming from inside a company; they come from another place or organisation (Cambridge Dictionary, 2017).

The next sections present the papers introduced in Table 2-2. First, it presents the characteristics of these models (sections 2.5.2 until 2.5.5), then section 2.5.6 (p. 48) provides a critical discussion of these works.

2.5.2 New Concept Development – NCD Model (Koen et al., 2002)

The NCD Model is a theoretical construct composed by comprehensive concepts, namely the controllable activities, "the engine" and the influencing factors. The controllable activities represent the elements that may be controllable by the organisation. The engine represents aspects controllable by the organisation and which are responsible for driving the FEI activities. Lastly, the influencing factors are relatively out of the control of the organisation (Koen et al., 2002). Table 2-4 shows the activities of this model.

Table 2-4 NCD Model (Koen et al., 2002)

Concept	**Elements**
Controllable activities	Idea Generation (IG) and Idea Enrichment (IE)
	Idea Selection (IS)
	Opportunity Identification (OI)
	Opportunity Analysis (OA)
	Concept Definition (CD)
"The engine"	Culture (CULT)
	Leadership (LD)
	Business strategy (BS)
Influencing factors	Organisational Capabilities (OC), the Outside World (OW), Customer and Competitor Influences (CCI) and Enabling Sciences and Technology (EST)

In this model, the authors consider the nature of work carried out on FEI as iterative and complex. Therefore, the model was designed as a no sequential relationship model. Moreover, the inner parts of the model are called elements. The authors prefer activities instead of processes because the latter would implicate in the use of structure and points of control. Either ideas or concepts can iterate through the five elements (IG and IE, IS, OI, OA and CD). According to the authors, the starting point for the NCD might begin with the Opportunity Identification or Idea Generation and Enrichment.

2.5.3 Stage Gate® (Cooper, 2008)

The Stage-Gate model consists of an approach introduced in the mid of the 1980's. It summarizes the author's research conducted on the actions of successful project teams and businesses at the time in which they developed winning products (Cooper, 2009).

An organisational innovation performance may reflect several factors. For Cooper (2012) having an effective Stage-Gate system supported by effective governance is an important practice in order to achieve best results. Table 2-5 shows the FEI stages and activities according to the Stage Gate® Model (Cooper, 2008). The remaining activities of this model, related to the NPD and commercialization phase, are not evaluated in this study.

Table 2-5 Stage Gate® Model emphasis on FEI activities (Cooper, 2008)

Stage	**Description**	**Gate**
Discovery	Idea Screen	Gate 1
Stage 1	Scoping	Gate 2
Stage 2	Build Business Case	Gate 3

The innovation process according to the Stage Gate® Model is a series of stages. Every stage comprises a set of required or recommended best-practices activities essential for advancing the project to the next gate or decision point (Cooper, 2008).

Koen et al. (2002) view that the Stage-Gate is a linear innovation process. However, for Cooper the Stage-Gate is an iterative process: "inside stages, there is much looping, iterations, and back-and-forth play as the project proceeds; some activities are undertaken sequentially, others in parallel, and others overlapping" (Cooper, 2008, p. 216).

2.5.4 The Three Phase Front End Model (Khurana and Rosenthal, 1997)

The use of an oriented process for activities conducted in the FEI helps to ensure that product strategy, business strategy and resource planning are well integrated (Khurana and Rosenthal, 1998). Additionally, necessary executive reviews and core team roles are necessary (Khurana

and Rosenthal, 1998). Table 2-6 presents the phases covered by the Three Phase Front End Model (Khurana and Rosenthal, 1997).

Table 2-6 The Three Phase Front End Model (Khurana and Rosenthal, 1997)

Concept	**Responsibilities**
Foundation Elements	Product and Portfolio Strategy
	Product Development Organisation
Front End	Pre-phase zero (Preliminary Opportunity Identification, Market and Technology Analysis)
	Phase zero (Product Concept and Definition)
	Phase one (Product Definition and Project Planning)

This model emphasises the need to align the organisational and product strategy. In addition, there is an emphasis on understanding the interrelationship between the activities, which are considered as important as the activities themselves (Khurana and Rosenthal, 1997). Moreover, the model informs the degree of FEI activities implementation. This feature is helpful for organisation to assess their formal FEI process status.

2.5.5 Fuzzy Front-End Information Flow and Decision-Making Process (Reid and De Brentani, 2004; De Brentani and Reid, 2012)

This model relates to the levels of the decision-making process, the interfaces and key roles in the FEI, which is a characteristic trait of this approach. Reid and De Brentani (2004) offer an FEI model suitable for discontinuous innovations. According to the authors, "information typically is unstructured and is brought into the organisation by individuals without such activity being explicitly directed by other persons in the organization" (Reid and De Brentani, 2004, p. 177). Lastly, the model has the following interfaces: Boundary Interface; Gatekeeping Interface; and, Project Interface.

According to this model, discontinuous innovations move into the organisation in a different way than incremental innovation. In addition, discontinuous innovation tends to originate from the environment (Reid and De Brentani, 2004). The authors argue that through the proposed

model it is possible to look at the FEI "through the lens of the efficacy of information flows into and within the firm" (De Brentani and Reid, 2012, p. 83).

2.5.6 Discussion

These four models deal with the use of FEI activities such as those related to opportunity; activities accomplished by individuals in contact with the environment (technology and market); concept development; influencing factors – mostly market and technology information; scenario planning; competitors; organisational issues; innovation spectrum and outside world – to provide an effective concept to enter into the NPD. The focus, approach, the depth and the convergence of the employed concepts of these models vary as well as their degree of structuring.

An important contribution from the Cooper's model regards the Concept Test occurring before the final assessment, thus representing the anticipation of important decisions. This model has received improvements over time through the integration of both lean and agile approaches. Starting from the third generation of the model it has received significant improvements to provide a more agile perspective. These improvements were necessary as previous generations presented a lack of flexibility. The proposed Stage-gate process "consists of a set of information-gathering stages followed by go/kill decision gates" (Cooper, 2008, p. 214).

The paper "Integrating the Fuzzy Front End of New Product Development" by Khurana and Rosenthal (1997) identifies the key role organisational strategy plays as a driving force in the innovation process. The authors propose a model focused on the linkage between business and product strategy. Moreover, they emphasise the importance of a well-planned portfolio; the existence of an enabling organisational structure; the need to identify customer needs; and, the development of a well-defined product concept as a means for a successful NPD. For Gaubinger and Rabl (2013), this is a useful approach to visualise and structure FEI activities, to diminish the fuzziness and to facilitate the communication.

Koen et al. (2002) presents an important contribution to the FEI with the New Concept Development Model by providing methods, tools, and techniques suitable for managing the FEI. However, these tools are likely to be selected and used in a heuristic manner (Achiche et

al., 2013). The "NCD Model", proposed by Koen et al. (2002), consists of three parts, namely: The Engine, the Controllable Activity Elements, and the Influencing Factors. The first relates to aspects such as Leadership, Culture and Business Strategy. The second comprises the Opportunity Identification; the Opportunity Analysis; the Idea Generation and Enrichment; the Idea Selection; and, the Concept Definition. Lastly, the Influencing Factors are those related to the internal and external environment, namely Organizational Capabilities and the Outside World. According to the authors, all these factors may influence the entire innovation process from the very beginning until the final commercialisation phase.

Reid and De Brentani (2004) focus on FEI for radical innovations. As a result, they propose a model that aims to deal with risk more effectively and to consider the complexity that arises in disruptive innovations. Their proposal has a major focus on decision-making points. This emphasis on decision-making is valuable for organisations, as it provides a configuration that helps the flow of information, regarding the development of a new product. Furthermore, this theoretical model has received contributions and enhancements (De Brentani and Reid, 2012).

The Stage-Gate Model (Cooper, 2008) presents a more structured approach. This model also provides some tools and practical recommendations to deal with the FEI activities. However, it is a model not designed specifically to the FEI, as it also encompasses the NPD and Launch (Commercialization). One beneficial point of this model is that it covers radical and incremental innovation. Moreover, as previously mentioned, from the third generation on, the model acquired a more dynamic perspective providing the notion of iterations and concurrently development. The model still receives enhancements over time. However, due to the gates, a potential concept may have its development stopped too early. Moreover, it is a model that due to its characteristics may be adequate only for established companies.

The NCD Model (Koen et al., 2002), although it offers an encompassing view of the FEI with the controllable activities and an iterative model, it does not provide management guidelines or orientation flows. Therefore, it may be understood as a conceptual approach that lacks the modelling of the dynamic process of the FEI. This characteristic does not diminish the value of this work, as this is one of the most accepted models (Gregor & Hevner, 2015) and it brings several contributions to the field.

Khurana and Rosenthal (1997) and Reid and De Brentani (2004, 2012) presented a more conceptual approach that contributes to a better understanding of the flow and underlying system presented in this phase. An important contribution of Khurana and Rosenthal (1997) is the attention to organisational and strategic alignment with the FEI. These two models are convergent regarding the importance of the communication flow to the FEI. Although Reid and De Brentani (2004) provide a model for radical innovation, Khurana and Rosenthal (1997) consider the information flow as vital, regardless of the innovation type.

The information flow in Reid and De Brentani (2004) is a guideline for the FEI activities. This orientation is understandable, as this model stands for "a key proposition that there is an essential difference in the flow of information and in problem structuring for discontinuous, as compared with incremental, innovations" (De Brentani and Reid, 2012, p. 71). Referring to this, Martinsuo and Poskela (2011, p. 911) state that radical innovation "is about venturing into new markets with new technologies, sufficient time needs to be dedicated for bringing both the technical and market knowledge into the firm", which denotes the particularity that disruptive innovation demands. However, some works argue that there are no significant differences between radical and incremental innovation (Verworn et al., 2008).

The work of Khurana and Rosenthal (1997) represents one of the first successful attempts to modelling the nature of the FEI, as it depicts the importance of organisational role by presenting the Foundation Elements. Furthermore, it provides an encompassing management perspective for structuring the FEI Phases. However, the first phases lack some definitions as well as some concepts require clarifications. Other features missing in this model are the ones that in themselves characterise the dynamic of the FEI, for instance, an agile flow and iterations (or feedback loops). Lastly, this model does not contain feedback loops and it lacks flexibility.

These are general remarks concerning the key features of the models, including the main positive and negative points of these works. Table 2-7 to Table 2-11 offers a summarized analysis of these models considering the concepts: Opportunity, Idea, Concept Development, FEI Foundation and Outside World. The definitions of these concepts are shown in Table 2-3 p. 44.

The organisation of the next tables starting on Table 2-7 and up to Table 2-11 is the following:

- The first column states the phase or activity responsible for the concept;
- The second column indicates the main responsibilities comprised in the phase/activity; and,
- Lastly, the third column presents the roles envisioned by the authors for those phase/activities.

The opportunity concept demands a role, in other words, an actor that will unfold the opportunity to the organisation. This role might be individual or collective. In addition, three out of the four models contain the relationship of the opportunity concept with a role, see Table 2-7. In fact, only Koen et al. (2002) do not specify roles. The importance of a role to the opportunity concept is in accordance with the definition of opportunity confidence (OC) provided by Davidsson (2015, p. 675): OC "refers strictly to a particular actor's subjective evaluation of the attractiveness – or lack thereof – of a stimulus".

Table 2-7 explores the analysis of the opportunity concept for each author.

Table 2-7 Analysis of the Opportunity Concept

Phase/Activities	**Main responsibilities**	**Roles**
Opportunity Identification and Analysis (Koen et al. 2002)	Identification and analysis of opportunities. Assessment and definition of the customer, market and/or technology. Alignment of the opportunity with the business strategy and culture.	No emphasis on individual role. The NCD Model considers formal process and multifunctional team.
Scoping Idea (Cooper, 2002, 2008)	Preliminary market assessment. Preliminary technical assessment. Preliminary business & financial assessment. Recommendations & plans for building the business case.	Gatekeepers contributing to decision-making. This role may change from gate to gate depending on the evolving risk profile of the project. Governance roles. Senior people in the business. Cross-functional team.

Phase/Activities	Main responsibilities	Roles
Pre-phase zero (PP0) (Khurana and Rosenthal, 1997, 1998)	PP0 is responsible for preliminary opportunity identification with a market and technology analysis. It answers for identification of customer needs, market segments, competitive landscape, and business prospects. It demands a clear understanding of the existing business and technology plans. PP0 collaborates with product and portfolio strategy.	The core team. The project leader. The executive review committee and a senior manager. These roles are complementary.
Boundary Interface Gatekeeping Interface and Information Flows (Reid and De Brentani, 2004) (De Brentani and Reid, 2012)	Boundary Interface - This phase comprises a flow of information inward from the environment to the individual. It consists of the analysis of unstructured problems and it is where opportunities are identified. Gatekeeping Interface and Information Flows represent the point at which information flows from the environment and start the evaluation process in what concerns their relevance to the organisation.	The boundary-spanning individual. The emphasis is in the individual role that within the organisation plays an external role. The individual that plays the gatekeeping role guarantees the "flow of technology". He/she secures the quality and speed of information flow. This role may be formal or informal.

The next table presents a comparative view of a singular activity of the FEI - the idea. This concept represents a broad set of activities and its range varies from idea generation to market and technology analysis. Table 2-8 presents the manner by which the main FEI reference models address this concept.

Table 2-8 Analysis of the Idea Concept

Phase/Activities	Main responsibilities	Roles
Idea Generation Idea Enrichment Idea Selection (Koen et al., 2002)	The beginning, development, and results of a concrete idea. Examination, the definition of criteria for assessments and idea selection.	Cross-functional team. Champion. Decision makers.

Phase/Activities	**Main responsibilities**	**Roles**
Ideation Scoping Idea (Cooper, 2002, 2008)	The ideation phase is responsible for identifying possible product opportunities. Identify the opportunity by means of meeting customer needs and/or capitalising on a changing environment. Analysis of historical trends and estimation of future trends. Assessment of the market, customer´s industry, Internal assessment of the business. Define a product innovation and technology strategy for the corporation as well as future scenarios. Search for opportunities in the marketplace. Listen to the customer to uncover new opportunities and/or work with lead and/or innovative customers. Explore fundamental research.	Gatekeepers contributing to decision-making. Governance roles. Senior people in the business. Cross-functional team. *Note*: The role of gatekeepers may change from gate to gate depending on the evolving risk profile of the project.
Pre-phase zero (Khurana and Rosenthal, 1998)	Idea Generation, and Market & Technology Analysis.	The core team, the project leader, the executive review committee and senior manager. Their roles are complementary.
From Boundary interface until Project interface (Reid and De Brentani, 2004) (De Brentani and Reid, 2012)	These authors address that ideation (information flow) starts from the boundary interface until the project interface. Because the individual, the organisation, and the environment are interacting with a knowledge exchange.	Boundary-spanning role. Gatekeeping championing role.

The result of the FEI process is a concept. Therefore, FEI activities are at some degree related to the development of this concept. A recent study analysed 268 FEI works and its findings indicate that an FEI concept may represent a new or improved product (good or service), process, marketing method or organisational method (Teza et al., 2015). Table 2-9 shows the manner by which the main FEI reference models address the notion of the Concept.

Table 2-9 Analysis of Concept Development

Phase/Activities	Main responsibilities	Roles
Concept Development (Koen et al., 2002)	Provide the concept to the NPD or Technology Stage Gate.	Gatekeepers. NCD Teams. Cross-functional team.
Build business case (Cooper, 2002, 2008)	The main responsibilities of the Build business case entails: Research about the user needs-and-wants. Competitive analysis. Market analysis. Detailed technical assessment. Manufacturing assessment. Concept testing. Detailed business & financial analysis. Development of the business case including product definition, a project justification and project plans.	Gatekeepers contributing to decision-making. Governance roles. Senior people in the business. Cross-functional team. *Note:* The role of gatekeepers may change from gate to gate depending on the evolving risk profile of the project.
Phase zero Phase one (Khurana and Rosenthal, 1997)	Phase zero concerns Product concept and definition. It addresses the task of targeting the market, analysing the competitive landscape, and planning the expected time and resources to bring the product to the market. Thus, it identifies customer and user needs, technologies and regulatory requirements. Phase one produces the fine-tuning for the product definition, moreover it oversees the project planning. In this phase, it occurs the decisions related to product features and functions, market and design priorities. Furthermore, possible trade-offs may occur here, such as customer requirements versus technology and/or resource/cost constraints.	The core team. The project leader. The executive review committee and senior manager. Their roles are complementary.
Project Interface and Information Flows (Reid and De Brentani, 2004) (De Brentani and Reid, 2012)	The project interface starts after a discontinuous innovation being considered for possible development. This phase is still covered by the FEI, but once the innovation moves forward, it will be in the domain of the NPD. Thus, the project interface is responsible for a flow of information from the organisation to a project that is being studied in the first screening phase.	Corporate-level decision-makers and Project-level decision-makers.

The benefits of innovation for the overall success of a business are not new, as indicated by Gaubinger and Rabl (2013). The novelty is in the increasingly dynamic and complex economic environment compelling firms to stay competitive by developing new products in progressively shorter periods of time. This scenario may be divided into two components, an internal related to the organisation's structure to innovate and an external – the outside world with driving forces influencing the companies' innovation competence. Thus, Table 2-10 presents the analysis of the so-called FEI Foundation (see Table 2-3 for definition, p. 44).

Table 2-10 Analysis of FEI Foundation

Phase/Activities	**Main responsibilities**	**Roles**
The "engine" elements so-called leadership, culture and business strategy. (Koen et al., 2001)	These elements provide the organisational environment for successful sustainable innovation. They are organisational concepts that need to be considered if a firm wants to achieve a successful FEI process.	Continuous senior management. Leader.
Critical factors (Cooper, 2002, 2008)	The key responsibilities understood as critical success factors are: Predevelopment work; early product and project definition; organisational structure, design and climate; top management support; leveraging core competencies; successful decision-making process; quality of execution of key tasks; availability of resources; speed and a stage gate process.	Gatekeepers contributing to decision-making. Governance roles. Senior people in the business. Cross-functional team.
Product Development Organization (Khurana and Rosenthal, 1997)	Product Development organisation regards the organisational structure aiming to facilitate the product development. It demands a flow of communication and cross-functional sharing of responsibilities.	Decisions about the roles for the FEI activities are taken in this phase.
Organisational structure (Reid and De Brentani, 2004) (De Brentani and Reid, 2012)	In terms of organisational structure, the quality of Information Flow and Speed of Information Flow are two factors emphasised as of importance during the FFE for discontinuous innovations. "The broader organizational context is usually the final destination for information sharing by the gatekeeper for discontinuous innovation" (De Brentani and Reid, 2012, p. 79).	The boundary-spanning individual. The gatekeeping individual. A senior management. Project broker. A small group of individuals.

The Outside World (see Table 2-3 for definitions, p. 44) is an FEI concept necessary to be considered due to the constant exchange of information and knowledge of an organisation with the external environment. Table 2-11 explores these concepts in the main FEI reference models.

Table 2-11 Analysis of Outside World

Phase/Activities	Main responsibilities	Roles
The Influencing Factors (Koen et al., 2001)	The engine provides answers to the influencing factors that may affect the corporation. These are organisational capabilities, external variables such as customer, competitors, suppliers, new entrants, sciences and technology, and industry rivalry.	Mindful leadership. Partners.
Critical Factors (Cooper, 2002)	The author recommends a market driven and customer focused new product process. He also recommends attention to the world product in aspects such as an international orientation in product design, development and target marketing. In sum, Market and industry are critical factors.	Gatekeepers contributing to decision-making. Governance roles. Senior people in the business.
- (Khurana and Rosenthal, 1997)	The model advocates for an identification of customer needs, market, competitive landscape, value chain, business opportunities and alignment with existing business and technology plans - all inputs originated from the outside world. However, there is no explicit mention regarding a phase to the outside world.	N/A
- (Reid and De Brentani, 2004) (De Brentani and Reid, 2012)	The external environment of an organisation is continuously addressed by individual roles, which establish a communication flow onward and inward. There is no phase specifically dedicated to this topic as this is a key characteristic of the model as a whole.	The boundary-spanning individual. The gatekeeping individual.

The results of the analysis suggest that with the exception of the works of Cooper (2002, 2008) and Reid and De Brentani (2004), there is a lack of attention to the roles that must be played in each dimension of the FEI. However, the works of Reid and De Brentani (2004) and De Brentani and Reid (2012) are the ones which further develop the role that must be played in each of the FEI phases. In the remaining works, the roles are depicted in a general sense. Therefore, Reid and De Brentani contributed to deepening the understanding of the interface and the role played by individuals in the FEI activities.

Some models present a strong emphasis on opportunity identification and analysis but less in the idea phase, as seen in Khurana and Rosenthal (1998), Reid and De Brentani (2004) and De Brentani and Reid (2012). However, Koen et al., (2002) and Cooper (2008) fill this gap with a broad attention to both to the idea and the opportunity phase.

The literature review by Pereira et al. (2017) shows that the FEI topics receiving the greatest attention concern Organisational Capabilities, Concept Definition and Idea Generation. The organisational capabilities are an underlying topic in all models whereas the concept definition for most of the models is specifically conducted at the FEI. However, for Reid and de Brentani (2012), the project interface is a door where the idea if accepted goes to the post-Fuzzy Front-End stage. For these authors, the first screen is part of the project interface, as the concept progresses for project-level commitment. Consequently, it is not considered part of the FEI.

2.6 FEI Overview[5]

The following review aims at providing an overview of the manner by which the FEI has unfolded over the years by identifying the focus of the research conducted in this domain knowledge. Nonetheless, the methodological procedures of this integrative literature review are detailed in Chapter 3 of this thesis. This section presents the diversity and depth of topics approached in the field. The goal is to assess if the FEI literature remains highly dispersed (Eliens and Xavier, 2015).

This study offers an encompassing perspective by building on two FEI Reference Models. The analysis is based on the compilation, selection, and review of the content of 169 publications concerning the Front End of Innovation. The search included all articles indexed by SCOPUS until the end of 2015.

The theoretical framework for analysing the results was based on the model proposed by Koen et al. (2002) “New Concept Development” (NCD) (Figure 2-2). This approach is a method used and accepted by the Product Development Management Association (PDMA).

[5] This section reflects in a great deal the content of the published paper “Front End of Innovation: An Integrative Literature Review” Journal of Innovation Management; JIM 5, 1 (2017) 22-39.

Furthermore, the findings were also plotted into the "Three Phase Front End Model" (Figure 2-3) (Khurana and Rosenthal, 1997, 1998) to provide an additional analytical perspective. This model provides a wide perspective of the FEI processes at the same time as it is compatible with the definitions of "idea" and "opportunity" from the NCD Model.

An impressive 44 out of 169 articles regard the FEI as a framework, a model, a process, a tool, or a methodology. Appendix A presents the full list of the 169 papers organised in descending order per year. It also contains the title, authors and source of publication.

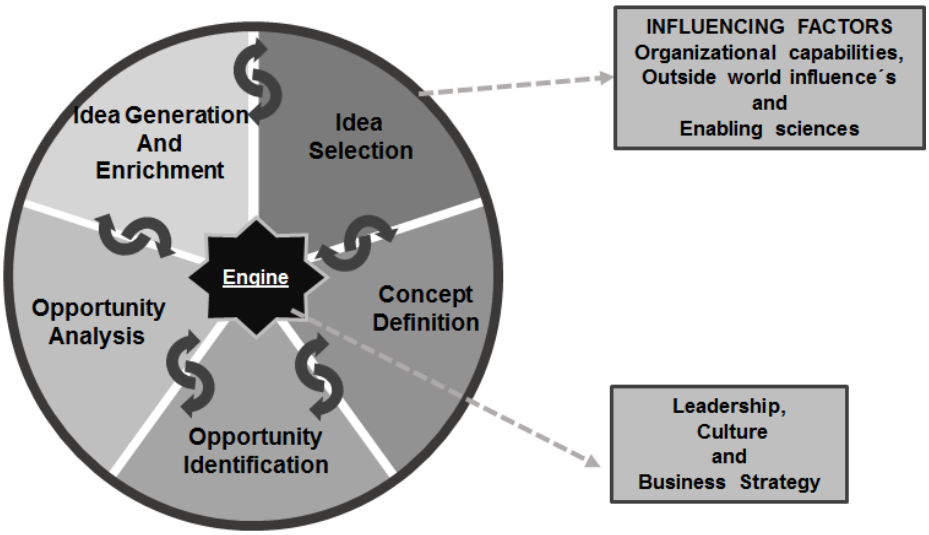

Figure 2-2 NCD Model as categories of analysis – Adapted from Koen et al. (2002)

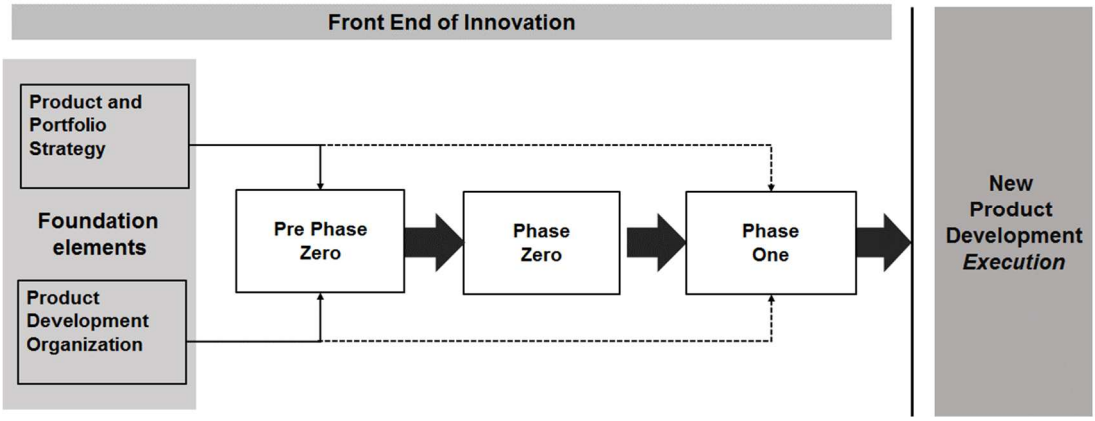

Figure 2-3 Three Phase Model of the Front End of Innovation as categories of analysis – Adapted from Khurana and Rosenthal (1998)

Table 2-12 presents the key of the categories of analysis used in the classification protocols and its acronyms. For more information about the content of the NCD Model and The Three Phase Model of the FEI see Sections 2.5.2 (p. 45) and 2.5.4 p. (46).

Table 2-12 List of acronyms used for the categories of analysis

NCD Model	**ACRONYMS**
Leadership	LD
Culture	CULT
Business Strategy	BS
Idea Generation and Enrichment	IGE
Idea Selection	IS
Opportunity Identification	OI
Opportunity Analysis	OA
Concept Definition	CD
Organizational Capabilities	OC
Outside World Influence´s	OWI
Enabling Sciences	EST
The Three Phase model of the Front End of Innovation	
Product and Portfolio Strategy	PPS
Product Development Organization	PDO
Pre-phase zero	PP0
Phase zero	P0
Phase one	P1

The analysis shows that increasing attention has been paid to the FEI in recent years. The term "Fuzzy Front End" was coined at the beginning of the 1990's, but the topic only became a consistently increasing trend in the field from 2006, reaching its peak in the years of 2011 and 2012. This period expresses the highest number of publications, as illustrated in Figure 2-4.

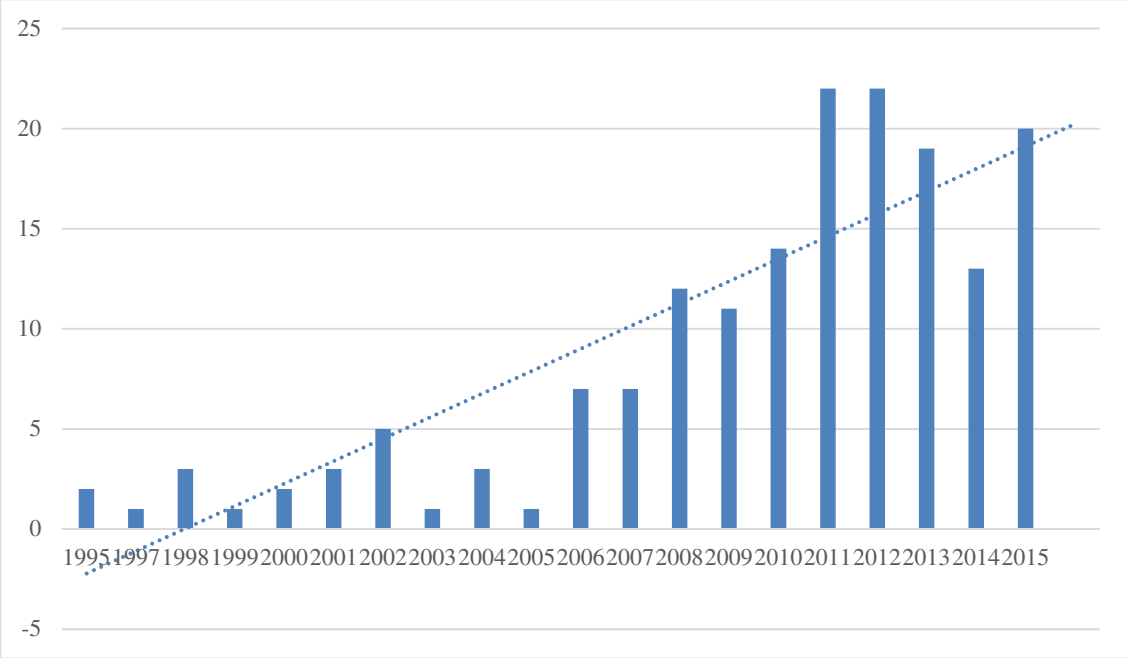

Figure 2-4 FEI works from 1995 to 2015

Figure 2-4 illustrates the trend of the 169 publications along the years, depicting a growing number of published papers in the field. It should be noted that this analysis makes no distinction between the type of innovation discussed in each paper.

- **Analysis Projected over the NCD Model**

The multidisciplinary nature of this field of knowledge leads to a scenario where one has a broad number of research topics, some recurrent in many papers, while others receive less attention. Table 2-13 displays the incidence of elements from the NCD Model, addressed from 1995-2015. It presents the number of publications per year (line) and per research topic (column).

Table 2-13 Incidence of elements from the NCD Model addressed per year, from 1995-2015*.

Year	BS	CD	CULT	EST	IGE	IS	LD	OA	OC	OI	OW	Total
1995					1				1			**2**
1997			1									**1**
1998					1				2			**3**
1999									1			**1**
2000				1					1			**2**
2001	1							1	1			**3**

Year	BS	CD	CULT	EST	IGE	IS	LD	OA	OC	OI	OW	Total
2002				1	1				3			**5**
2003									1			**1**
2004									3			**3**
2006	1	2							3	1		**7**
2007	1	3							1	2		**7**
2008	1	3			3			1	3	1		**12**
2009	2	4		1	1			1	1		1	**11**
2010	2	2			2			1	4	2	1	**14**
2011	4	3	1		3	1			6	2	2	**22**
2012	3	1	1		6	1		1	6	2	1	**22**
2013	1	6	1		6		1	1	1	2		**19**
2014					4				6	2	1	**13**
2015	1	1		1	5				8	4		**20**
Total	**17**	**25**	**4**	**4**	**33**	**2**	**1**	**6**	**53**	**18**	**6**	**169**

* Appendix A offers a list of these publications.

Although the number of papers has been increasing over time, topics such as Leadership, Idea Selection, Enabling Sciences and Culture have only received limited attention. As illustrated in Table 2-13, the findings suggest that some areas have received more attention in quantitative terms, such is the case of Organisational Capabilities. OC is an umbrella term covering topics varying from structure, resources, capabilities and competencies to processes, norms and efficiency, which may partly explain its high number of hits. Idea Generation and Enrichment (IGE) is also quite encompassing, as it includes: the means, incentives, methods, tools, techniques and resources used for IGE activities.

Another topic that received important contributions is the Concept Definition (CD). This activity involves an important task in the process, as it represents the input for the New Product Development and Commercialisation phases.

It is now relevant to consider the structure of the NCD Model to analyse the results. Table 2-14 shows the configuration of the NCD. Furthermore, it builds on the definitions proposed by Koen et al. (2002). In this context, the evidence suggests:

- More attention was given to the Organisational Capabilities (OC), which is part of the Influencing Factors in the NCD Model.
- Controllable Activities receive a broad attention in FEI publications (related to topics such as Idea Generation and Enrichment, Concept Definition and Opportunity Identification).

Table 2-14 NCD Model's composition

Part of the Model	**Content addressed**
Engine	Leadership – LD Culture – CULT Business Strategy – BS
Elements (Controllable Activities)	Idea Generation and Enrichment – IGE Idea Selection – IS Opportunity Identification – OI Opportunity Analysis - OA Concept Definition - CD
Influencing Factors	Organisational Capabilities - OC Outside World Influence´s – OW Enabling Sciences and Technologies -EST

The part of the model that has received less attention, regarding the number of publications, was the Engine. It covers topics such as Leadership, Culture and Business Strategy. The relevance of these topics was addressed in a recent study (Koen et al., 2014a, 2014b) where 197 empirical cases on successful Front-end practices were analysed. The study highlighted the importance of senior management commitment, vision, strategy, and resources.

As the major contribution regarding the volume of publications is from 2006, Figure 2-5 illustrates the inner parts of the "NCD Model" showing the number of publications over the last years.

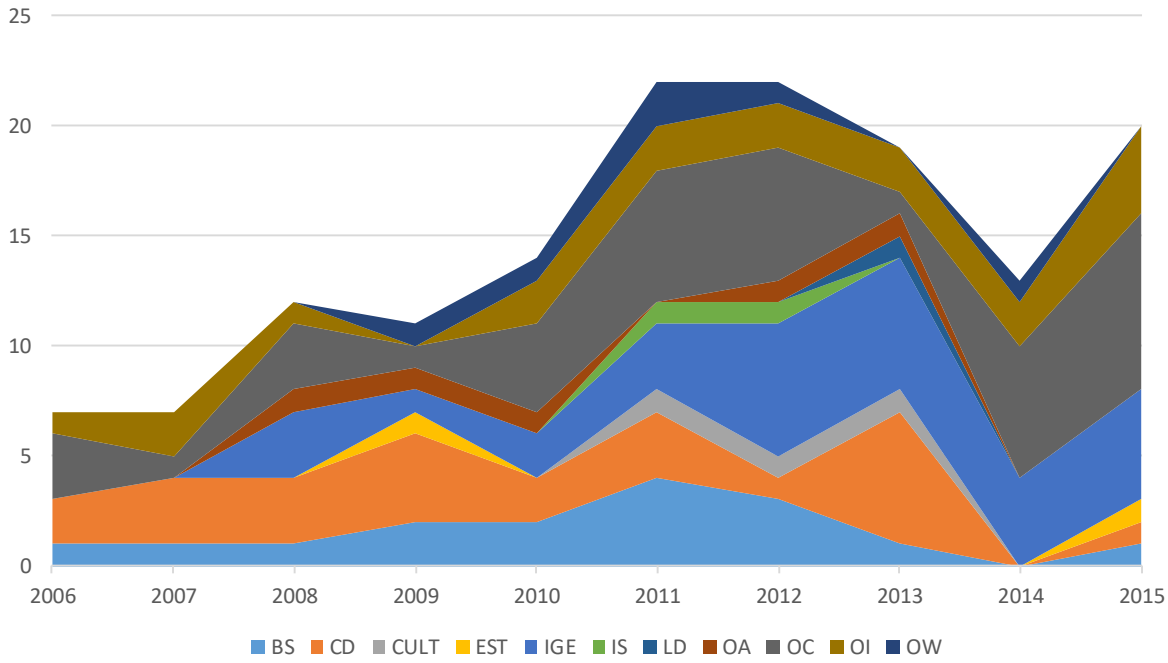

Figure 2-5 Inner parts of the NCD Model addressed per year, 2006 – 2015

- **Analysis Projected over the Three Phase Front End Model**

In order to provide a comparative visualisation of the analysed data, the 169 papers were also classified following the framework of analysis proposed by Khurana and Rosenthal (1998). In this approach, the FEI activities include product strategy formulation and communication, opportunity identification and assessment, idea generation, product definition, project planning and executive reviews. The "Three Phase Front End Model" (Khurana and Rosenthal, 1997, 1998) is organised as illustrated in Table 2-15.

Table 2-15 The Three Phase Front End Model

Concept	**Responsibilities**
Foundation Elements	Product and Portfolio Strategy - PPS Product Development Organization - PDO
Front End	Pre-phase zero (Preliminary Opportunity Identification, Market and Technology Analysis) – PP0 Phase zero (Product Concept and Definition) – P0 Phase one (Feasibility and Project Planning) – P1

This model emphasises the organisational alignment and the product strategy. The authors further highlight the immense value of the interrelationship between activities, which are considered as important as the activities themselves (Khurana and Rosenthal, 1997). Taking into account this framework of analysis, the result of the analysis of the 169 papers is shown in Table 2-16.

Table 2-16 Finding results according to the Three Phase Front End Model

Year	P0	P1	PDO	PP0	PPS	Total
1995			1	1		2
1997			1			1
1998			2	1		3
1999		1				1
2000			1		1	2
2001			1	1	1	3
2002			3	2		5
2003			1			1
2004			3			3
2005			1			1
2006	2	2	2		1	7
2007	2	1	1	2	1	7
2008		3	2	5	2	12
2009	2	4		2	3	11
2010	1		5	5	3	14
2011	3	2	8	4	5	22
2012	2		9	9	2	22
2013	6		7	6		19
2014	1	4	5	3		13
2015	4	4	5	6	1	20
Total	**23**	**21**	**59**	**47**	**20**	**169**

Based on these results, the parts of the model that have received more attention from 1995 to 2015 were respectively PDO (Product Development Organization) and PP0 (Pre-Phase Zero). The Product Development Organization relates to an organisation structure, roles, incentives, and norms, which is an important support for the efficiency of the FEI. PP0 performs Preliminary Opportunity Identification, Market, and Technology Analysis. In this case, the two

most expressive concepts regarding the number of contributions represent the two parts of the Model, respectively the Foundation Elements and the Front End itself.

The areas that have received less attention are Product and Portfolio Strategy (PPS), Phase One (P1) and Phase zero (P0), as depicted by the small number of publications. Phase One deals with feasibility issues and project planning. Moreover, Phase Zero shapes the product concept and definition. Alternatively, Product and Portfolio Strategy address the need of a clear product strategy and a well-planned portfolio of new products.

Figure 2-6 illustrates the inner parts of the "Three Phase Front End Model" (Khurana and Rosenthal, 1997, 1998) depicting the attention received over the last years.

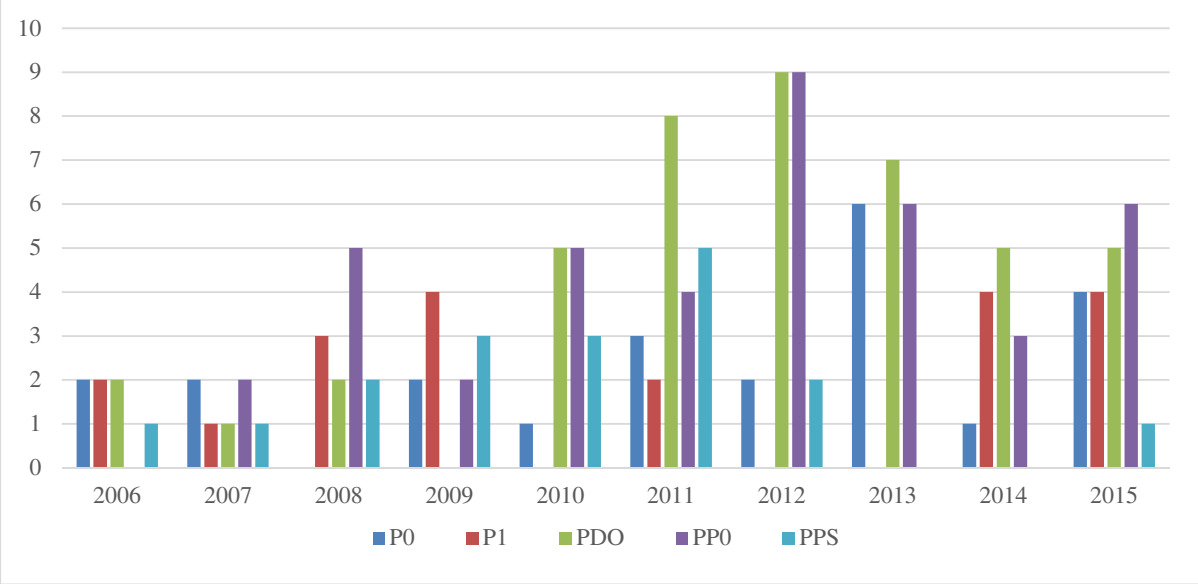

Figure 2-6 FEI publications through the lens of the Three Phase Front End Model

The evolution in the number of publications over time reveals the emergence of the FEI in recent years. Until 2005, this topic received limited attention. In 2006, the research focus started to widen with the first publications on the topic of "Opportunity Identification" (OI). Special attention must be given to years 2011, 2012 and 2013 that show an increase in the number of papers and the broadening of research perspectives, thus bringing more diversity of contributions to the FEI research (Figure 2-4). This scenario suggests that an in-depth

understanding of the FEI phenomena may have fostered the need to broaden research into new directions.

In the context of the NCD Model classification framework, there is a substantial lack of contributions to topics related to Leadership, Enabling Sciences and Technologies, Culture, Idea Selection and Opportunity Analysis. The relative weight of these components is illustrated in Figure 2-7 as percentages, where Leadership and Idea Selection get only 1%, the lowest value.

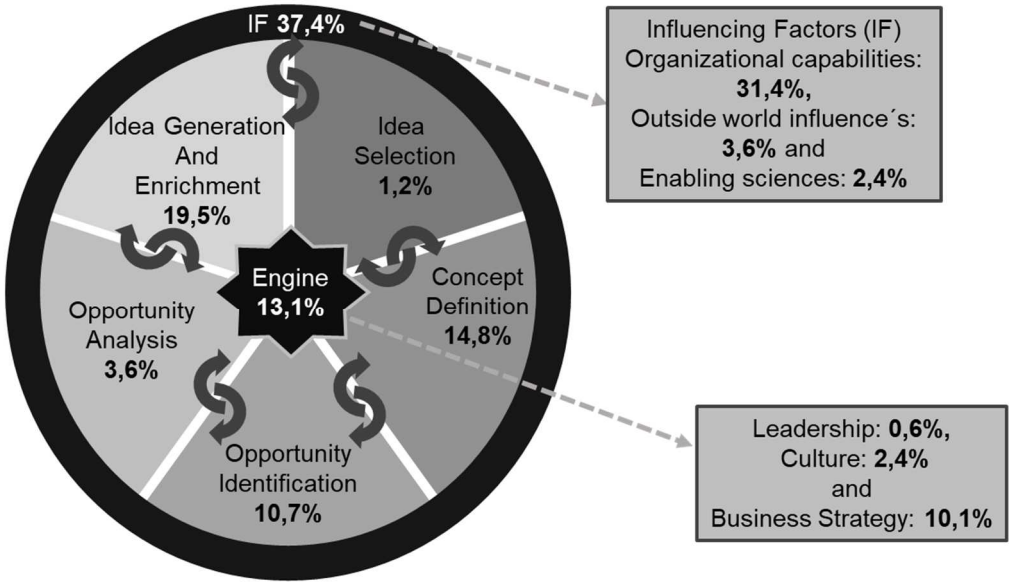

Figure 2-7 Research findings through the lens of the NCD Model

Regarding the "Three Phase Front End Model," results show that the area with less emphasis is "Phase One", which covers topics related to the analysis and decisions about the feasibility of the developed concept and the issues related to project planning. Figure 2-8 pictures the relative weight of the different "Three Phase Front End Model" components.

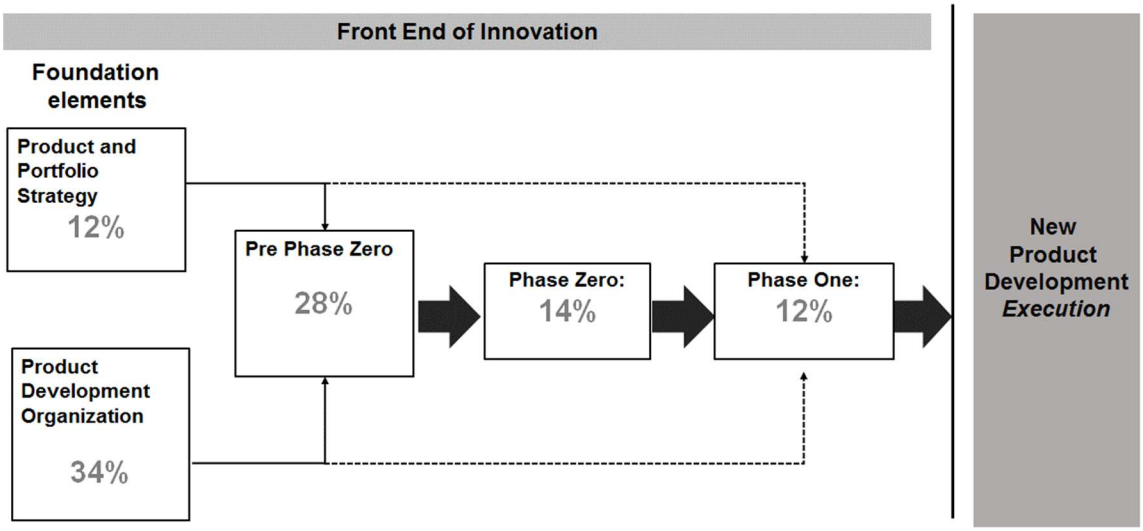

Figure 2-8 Research findings through the lens of the Three Phase Front End Model

In both models, the topics addressing organisational issues were the ones that received more attention. Organisational competencies are indeed important as they may be considered the means to provide the basis for FEI activities.

Concerning the "NCD model", the parts more frequently addressed by research were "Organisational Capabilities", "Idea Generation and Enrichment", and "Opportunity Identification". These results agree with the findings from the projection into the "Three Phase Front End Model" that reveal more attention was given to "Product Development Organisation" (PDO) and "Pre-Phase Zero" (PP0). The latter phase covers the "Preliminary Opportunity Identification" and the "Market and Technology Analysis".

The least frequently addressed topics, in the context of the "NCD Model", were "Leadership", "Idea Selection", and "Enabling Sciences". These topics are not explicitly handled in the "Three Phase Front End Model" and would likely fall into "Product Development Organisation" (PDO). The higher granularity of the "NCD Model" leads to less publications per topic, in contrast to Table 2-16 (p. 64) where the lower granularity of the "Three Phase Front End Model" leads to a less unbalanced distribution of publications in each phase.

2.7 Technology Management

In what concerns the context of the Front End of Innovation, it is important to emphasise the need for ensuring a constant input of market and technology expertise throughout the FEI process and not simply at the Idea Generation Stage (Brem and Voigt, 2009). The contribution of Markham and Kingon (2004, p. 72) is vital in this matter, since for them "central to the logic and technique of turning technical advantages into product advantages is linking technical performance capabilities with enduring customer needs".

Technology Management (TM) is an evolving field. In the beginning, studies had a restricted view of TM activities/processes, which was mainly limited to R&D activities in companies (Cetindamar et al., 2009). Drejer (1996) enumerates four schools that evolved over time, namely: R&D Management, Innovation Management, Technology Planning, and Strategic Management of Technology (MOT).

For Prajogo and Sohal (2006, p. 298): "both technology and R&D management have been well acknowledged as the major resources for achieving high innovation performance". Furthermore, for Erensal et al. (2006), Technology Management is a vital determinant of long-run success or failure of organisations. In a broad sense, TM allows "organizations to enter new markets, renew existing product lines and keep up with rapid technological developments in the environment where they survive. Among all the influences in an organisation environment, technology management is the key factor that may provide long-term competitive advantages" (Erensal et al. 2006, p. 2756).

Cetindamar et al. (2009) analysed TM activities in order to provide a general understanding of the types of TM core activities. Their study builds on previous works (Cotec, 1998; Levin and Barnard, 2008; Dogson,2000; Roberts,1988; Rush etal.,2007). The identified TM activities are:

a) Identification of technologies that are (or it is expected to be) of importance to the business.
b) Selection of technologies that should be supported by the company.
c) Acquisition of chosen technologies.

d) Exploitation of technologies in order to generate profit or other benefits the company intends to accomplish.
e) Protection of knowledge and any other expertise that is embedded in products and business systems.
f) Learning capabilities concerning the development and exploitation of technologies.

This set of TM activities supports the development of innovative capabilities. For instance, the type of innovation, the knowledge and requirements to develop a product, and the firm's capability will impact the innovation system of a company.

Bren and Voigt (2009) argue that technology and technology-oriented companies are usually more influenced by recent technologies than other companies. Complementing this view, Markham and Kingon (2004) explore that innovative technology may offer countless advantages, but companies cannot expect that customers and markets will know about the new technology. Hence, systematic planning is required to express new technical advantages as products that meet customers' needs.

Early and preliminary technology and market assessments are frequently required as a first step toward the FEI process. Following the Opportunity Identification, there is the Opportunity Analysis that involves an assessment of the opportunity to confirm whether it is worthy to invest on it. Therefore, some additional information may be required in order to translate the identified opportunity "into specific business and technology opportunities" (Koen et al., 2002, p. 17).

The following sections explore the Roadmapping, Lead User and Technology Product Market (TPM) methods. The purpose is to analyse and to explore the technological assessments as well as the roles played by these methods in the FEI.

2.7.1 The use of Technology Roadmapping - TRM

Since the early 2000's, Technology Roadmapping (TRM) has been receiving increased attention from both academics and practitioners (Lee & Park, 2005). The use of Roadmapping provides a framework that helps organisations to manage their technological future (Rinne,

2004). Nonetheless, TRM has been developed with greatly differing levels of specificity according to the targeted public (Rinne, 2004). The TRM is a flexible and powerful approach broadly used in industry for strategic purposes and for integrating business and technology (Amer and Daim, 2010).

However, there are those who claim "the roadmapping methods found in the literature were created to suit the context of large corporations, which combine R&D and product development structures, i.e., organizations that mainly adopt the market pull strategy and closed innovation to define technologies to be developed based on specific market needs." (Caetano and Amaral, 2011, p. 1427).

In a literature review of the period from 1997 to 2011, Carvalho et al. (2013) have found that the size of the company addressed in research was not explicitly stated in most of the papers, some works focused on SME companies, large companies, academia and government. These arguments about the use of technology roadmapping may be an evidence of a variety of situations that TRM can be used. Moreover, the TRM is by essence adaptable regarding objectives, timeframe, architecture, processes, and graphical format (Phaal et al. 2003).

The focus of research about technology roadmapping has been on management of technology and innovation (Vatananam and Gerdsri, 2010). Also, the value of technology roadmaps may be evident in the use of technology planning, technology selection, and technological innovation (Rinne, 2004). For Amer and Daim (2010, p. 1356): "TRM applications include business strategy development, policy formulation, product and technology planning, strategy planning, understanding technology trends, keeping track of product & technology breakthroughs, and prioritisation of R&D and product development projects".

Despite the variety of roadmapping process, "there is a consensus about the three main phases that must be considered: preparation (when decisions are made); implementation (when initiatives are executed) and finalization, when the results of the process are consolidated and disseminated and major decisions are made about the continuation of the process" (Caetano and Amaral, 2011, p. 1429).

TRM is a useful technique due to its integrative power. The TRM increases cross-functional communication and core processes to innovation and development (Lee and Park, 2005), both characteristics are suitable to the FEI.

2.7.2 The use of the Lead User Methodology

There is an ongoing interest in the use and research of the Lead User methodology in the new product/service development (Franke et al., 2005; Schreier and Prügl, 2008). The Lead User Methodology may be applied in Innovation Management and Technology Forecasting, for instance as a basis for the decision-making process (Trott, Duin, & Hartmann, 2013).

The term *user* may be understood as firms or individual consumers, which benefit from the use of a product or service (von Hippel, 2005). The term Lead Users embodies two main characteristics "They are (1) at the leading edge of an important market trend and (2) they have a high need for solutions to the novel needs they have encountered at that leading edge." (von Hippel et al., 2009, p. 1398).

Therefore, Lead Users placed on the leading edge of trends will consequently encounter needs before most of the market, which may experience this need at a later stage (Schreier and Prügl, 2008). Of note, Lead User Innovations might have commercial appeal if they match the future needs of the market (Schreier and Prügl, 2008). Therefore, LU is a valuable contributor to the FEI.

Lead Users innovate because they have a distinctive knowledge, as compare to other users, as well as they have the necessary expertise (Trott et al., 2013). However, attention should be given to the use of Lead User methods as a source of innovation, as "empirical research on the sources and patterns of innovation makes clear that users are just one of many different sources of innovation" (Trott et al., 2013, p. 129). The integration of the Lead User in the FEI is a vital tool to diminish the typical uncertainties at the beginning of the innovation process.

The identification of Lead Users consists of a common difficulty of this method. As emphasised by Schreier and Prügl: "a thorough understanding of what factors impact consumers' leading-edge status and whether lead users can be differentiated from ordinary users using certain

behavioral patterns might help" (2008, 332-333). An answer to this problem consists of the use of the Pyramiding technique.

This method is an adequate approach to apply in the FEI as Lead Users have been found to bring commercially attractive user innovations. Furthermore, LU has been shown to be a highly promising source of innovation (Schreier & Prügl, 2008).

2.7.3 The use of Technology Product Market - TPM

There is an old debate about technology push *vs* demand pull (Balconi et al., 2010). The technology Push (TP) can be considered as creative and/or destructive, it yields new or major improvements (Brem and Voigt, 2009). Market Pull (MP), nevertheless, constitutes of replacements or substitutions (Walsh et al., 2002). These approaches commonly describe innovations as originally derived from technology advancements or market need.

Systematic planning helps companies to face the challenge of sustaining innovation by proposing an adequate way to express new technical advantages using products that meet customer needs (Markham and Kingon, 2004). Therefore, the framework technology-to-product-to-market (TPM) aims at translating unique technical capabilities into product characteristics that match customer needs (Markham and Kingon, 2004).

Nonetheless, the Front End of Innovation requires a constant input of market and technology expertise throughout its development, not only within the stage of idea generation (Brem and Voigt, 2009). Consequently, an iterative tool, such as the TPM, addresses this problem.

The TPM process starts by finding technologies that could be leveraged by its unique advantages (understood as new capabilities). These capabilities are then manifested as product features. Afterwards, the product concept is presented to specialists in the field and possible lead customers within specific potential market segments to be validated. In summary, "If information about the product is disconfirming, that product or market segment idea is eliminated. Alternative or improved product concepts are generated and presented in an iterative manner until a product concept finds strong positive response within one or more intended market segments." (Markham and Kingon, 2004, p. 72-73).

In short, neither MP or TP can be claimed as the right way to sustainable innovations, as organisational and external variables need to be considered in the FEI process. Both TP and MP have drawbacks (Markham and Kingon, 2004). Companies need to have their attention in evaluating both the technology and the market, in order to be effective and efficient in this process. Hence, a mixed approach may benefit the introduction of innovative technologies in the market by identifying and assessing technology feasibility, future needs and demands that meet the portfolio of the company.

The previous sections provided an overview of the important and seminal contributions to the FEI domain. It also presented the Technology Management contributions to the beginning of the innovation process. Altogether, an in-depth analysis of the main FEI reference models suggests that this knowledge field still demands a comprehensive and integrative approach. Therefore, it becomes evident the need for a comprehensive and integrative FEI model.

This integrative model is best represented in the form of an ontology. An ontology is a model that holds the capacity of communication between humans and machines, between humans as well as between software agents (Uschold & Grueninger, 1996; Noy & McGuiness, 2001). Hence, an ontology is a useful knowledge representation to cover a wide-ranging view of the FEI activities, responsibilities, processes, relationships and outputs.

2.8 Ontologies

An ontology defines a common vocabulary for researchers that need to share information in a domain (Noy & McGuinness, 2001). Its benefits extend to several contexts, including those of knowledge-intensive applications. Unlike conceptual models, an ontology further explores concept relations providing a blueprint for humans and machines, therefore enhancing the effectiveness of the knowledge representation. In sum, ontologies provide formal models of domain knowledge that can be exploited in different ways (Suárez-Figueroa, García-Castro, Villazón Terrazas, & Gómez-Pérez, 2011).

As such, ontologies have been developed in Artificial Intelligence (AI) to facilitate knowledge sharing and reuse. Moreover, ontologies have been applied in several expert systems of

numerous types of industries (Cristani & Cuel, 2005). Likewise, Design Science (DS) has been used to develop ontologies, for instance, the Business Model Canvas comes from the research thesis of Ostewalder (2004). Another example consists of the ontology developed by Bullinger (2008). It defines a shared language for ideation, focusing on assessment and selection of ideas, considering the beginning of the innovation process.

Concerning an engineering perspective on the development of an ontology, Gruber (1995) sees a formal ontology as designed artefacts formulated for specific purposes and evaluated according to specific design criteria. Therefore, an ontology is "(…) an explicit specification of a conceptualization" (Gruber, 1995, p. 908) while conceptualization is "an abstract, simplified view of the world that we wish to represent for some purpose" (Gruber, 1995, p. 908). This definition comprises an engineering perspective, the term ontology is used accros several knowledge domains and has different interpretations in different fields, such as philosophy, logic, design.

Another definition considers an ontology as a common vocabulary for researchers who need to share information in a domain. It includes machine-interpretable definitions of basic concepts in the domain as well as relations among them (Noy & McGuinness, 2001). For these authors, some of the reasons to develop an ontology are:

- To share collective understanding of the structure of information between people or software agents;
- To enable reuse of domain knowledge;
- To make domain assumptions explicit;
- To separate domain knowledge from the operational knowledge; and
- To analyse domain knowledge.

2.8.1 Methodologies to develop ontologies

A critical activity to develop an ontology concerns the identification of the requirements for an ontology (Suárez-Figueroa, Gómez-Pérez & Villazón-Terrazas, 2009). The Ontology Requirements Specification – ORS is a document that describes what an ontology should support. Moreover, the ORS contains the sketched planned area of the ontology application

(Staab, Studer, Schnurr, & Sure, 2001). At the early stage of the ontology development, two actions are valuable, one consists of defining the set of ontological inputs to develop the ORS (Suárez et al. 2009) while the other concerns the identification of developed and potentially reusable ontologies (Staab et al., 2001).

An ontological model is much more than a classification of knowledge into categories. It allows known facts and/or assumptions to be reasoned, by means of deriving a conclusion or making inferences (Feilmayr & Wöß, 2016), according to the authors the main benefits of ontologies are:

- Sharing Principle – that goes beyond a taxonomy, once it addresses the complexity of a shared and transferable knowledge;
- The Semantic Expressiveness – an ontology surpasses taxonomies and other models as it allows models to be designed to capture complex real-world concepts, as it considers their semantics;
- Complex Models – the delineation of ontological relationships combined with other ontology design features allows for the creation of complex and expressive models; and,
- The size of Sharing Community – there is a broad audience that benefits from the ontology – the ontology stakeholders are broader than entity-relationship models.

These are important benefits for the FEI knowledge domain, as it provides the ability, through an FEI Integrative Ontology, to overcome inconsistencies concerning the existence of different constructs, concepts and definitions. Furthermore, the current variety of FEI approaches in models and constructs may cause difficulties for academics as well as for practitioners.

According to Suárez-Figueroa et al., (2011) Methontology, On-To-Knowledge, and Diligent were the most cited methodologies for building ontologies until 2009.

- Methontology: provides guidelines for specifying ontologies at the knowledge level, as a specification of a conceptualisation (López, Gómez-Pérez, Sierra, & Sierra, 1999). This methodology also comprises a list of activities demanded for ontology reuse and re-engineering processes. However, Methontology does not offer detailed guidelines

for such activities, nor does it consider different levels of granularity. It also does not consider the reuse and re-engineering of non-ontological resources (Suárez-Figueroa et al., 2011).

- On-to-Knowledge: this methodology builds ontologies considering how they are going to be used in knowledge management applications (Staab et al., 2001). The processes proposed by this methodology are the following: feasibility study, kick-off (where ontology requirements are identified); refinement (where a mature and application-oriented ontology is produced); evaluation, and maintenance (Suárez-Figueroa et al., 2011).
- Diligent: this methodology "is intended to support domain experts in a distributed setting to engineer and evolve ontologies with the help of a fine-grained methodological approach based on Rhetorical Structure Theory, viz. the DILIGENT model of ontology engineering by argumentation" (Pinto, Staab, & Tempich, 2004, p. 1). Diligent pays attention to collaborative and distributed ontology engineering. The ontology development process comprises five activities: building, local adaptation, analysis, revision, and local update (Suárez-Figueroa et al., 2011).

A more attainable approach consists of the Methodology 101 (Noy & McGuinness, 2001). For these authors, the design of an ontology may consist of seven steps, which encapsulates the author's definition of an ontology:

> *"an ontology is a formal explicit description of concepts in a domain of discourse (classes (sometimes called concepts)), properties of each concept describing various features and attributes of the concept (slots (sometimes called roles or properties)), and restrictions on slots (facets (sometimes called role restrictions)). An ontology together with a set of individual instances of classes constitutes a knowledge base."(Noy & McGuinness, 2001, p. 3).*

Consequently, the steps address:

1. Determine the domain and scope of the ontology;
2. Consider the reuse of existing ontologies;
3. Enumerate the importance of terms in the ontology;
4. Define the classes and the class hierarchy;
5. Define the properties of classes – slots;
6. Define the facets of the slots;
7. Create instances.

The process of building an ontology involves several more decisions. For instance, the definition of the language that will be used, the selection of the framework as well as methods and tools; the definition of the granularity of the ontology and ontology limitation concerning the competence questions. Nonetheless, the validation, assessment and maintenance of the ontology are important steps to be considered.

2.9 Conclusions

The literature frequently address the "fuzziness" of the FEI, however, the entire innovation process demands sophisticated and active management (Bessant et al., 2005). As a result, valuable contributions have been made to the FEI domain, yet, there is still room for further research. This work advocates for the use of a systematic approach to manage the FEI, in order to integrate the activities developed in the preliminary stage of the innovation process. This approach should be comprehensive and integrative suitable to the FEI nature. The solution must also be well-adjusted to include the outside world, the organisational capabilities as well as the organisational strategy. Finally, an iterative FEI approach may be fine-tuned over time in order to enhance NPD over the long term.

The main results of the literature review show that:

- Some models present a strong emphasis on opportunity identification and analysis in detriment to the idea phase.
- All models addressed the organisational capabilities, to some extent, as a means of providing a basis for FEI activities.

- The main FEI reference models overlook the roles played by the FEI actors concerning the phases and activities of the FEI. An exception is found in the works of Cooper (2008) and Reid and De Brentani (2004).
- The review also assessed one model regarding radical innovation, as this analysis clarifies the understanding of both incremental and radical innovation.

The competitive landscape presents a challenge for corporations. Thus, it demands an assertive and successful New Product Development. Entrepreneurs and firms are confronted with the need to manage the innovation process, in order to produce sustainable innovation. In sum, the literature demonstrates that the FEI is a critical phase for the success of NPD.

Evidence shows that the FEI has received greater attention in recent years both regarding depth and number of publications. However, there are still pending gaps, namely:

- Regarding the applicability of modern approaches in the FEI, Gonzáles (2014) uncovered insufficient findings for the use of agile project management;
- There is little research focusing on the Management of this phase of the innovation process (Robins and O'Gorman, 2015);
- Eliens and Xavier (2015) highlight the high number of publications related to tools and methodologies. Although these works bring some insights to the field, most of the contributions address the effect of a specific tool on a particular FEI process. As a result, many publications do not generate a substantial amount of knowledge for the FEI research field as a whole. There is a lack of contributions regarding the so-called process activity models (mapping of the entire FEI process).
- The FEI requires a holistic approach and an innovative mindset. Possible trends worthy of attention relates to the use of ICT technologies. For instance, "software to explore and track technological trends, nethnographic procedures to observe user behaviour and collect user ideas online, technical advancements to increase the validity of virtual prototyping" (Gassmann and Schweitzer, 2013, p. 302). An example of such research effort may be found in Barradas & Rodrigues (2016).

These arguments stress the relevance of building a comprehensive body of knowledge in the area of the Front End of Innovation as a multi-disciplinary research domain.

Chapter 3 Research Methodology

The research methodology in this thesis follows a multi-disciplinary approach. Consequently, it employs a combination of qualitative and quantitative methodologies, having a so-called mixed approach. This study adopts the Design Science due to the nature of the FEI and the proposed research problem, which addresses a real problem faced by companies and entrepreneurs to overcome the challenge of innovation.

3.1 Integrative Literature Review

Prior to defining the research strategy, it was conducted an integrative literature review, defined by Torraco as, "a form of research that reviews, critiques, and synthesises representative literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated." (Torraco, 2005, p.356). The integrative literature review for the Front End of Innovation provided an overview of the topic as well as the means to draw a comprehensive picture of what has been studied in the scope of the FEI. Thus, the review contributed to delimitate the research problem.

3.1.1 Data collection procedures

The integrative literature review comprised the analysis of 169 papers, retrieved from Scopus, a reputable multidisciplinary scientific database. Scopus and Web of Science offer quite similar functionalities and coverage (Öchsner, 2013). However, Scopus gathered the greatest number of active titles in February of 2014 (Scopus, 2014).

The search was conducted for the following predefined subject areas, as listed by Scopus:

> Business, Management and Accounting; Engineering; Computer Science; Decision Sciences; Economics, Econometrics, and Finance; Social Science; Material Science; Arts and Humanities; and, Psychology.

The following areas were excluded from the query:

> Energy; Medicine; Chemical Engineering; Physics and Astronomy; Agricultural and Biological Science; Environmental Science; Chemistry; Earth and Planetary Sciences; Biochemistry, Genetics, and Molecular Biology; Health Professions; Nursing; Pharmacology, Toxicology, and Pharmaceutics; Immunology and Microbiology; Mathematics; and, Neuroscience.

Furthermore, the search only considered documents classified as “article”, in order to ensure that all of the selected works were subjected to a peer review process.

The database query included the following fields: “Article Title”, “Abstract”, “Keyword” and "within". The latter consists of the proximity indicator filter. Its notation consists of “W/n” and the query below exemplifies its use.

> "Front end" of W/8 innovation

The proximity indicator searches for “innovation” within the next eight words in the text. This search configuration leads to a result with a larger number of articles related to the research goal.

Figure 3-1 shows the results of the possible query nomenclatures. The results illustrate the higher occurrence of the term “front end” compared to other possible formulations. Therefore, the chosen query consists of the term “front end”.

The term “Fuzzy Front End” includes the use of the expression “Front End”, hence the research did not consider this term as a possible query. Moreover, the Scopus database makes no difference regarding the use of hyphen for “front-end” or “front end.”

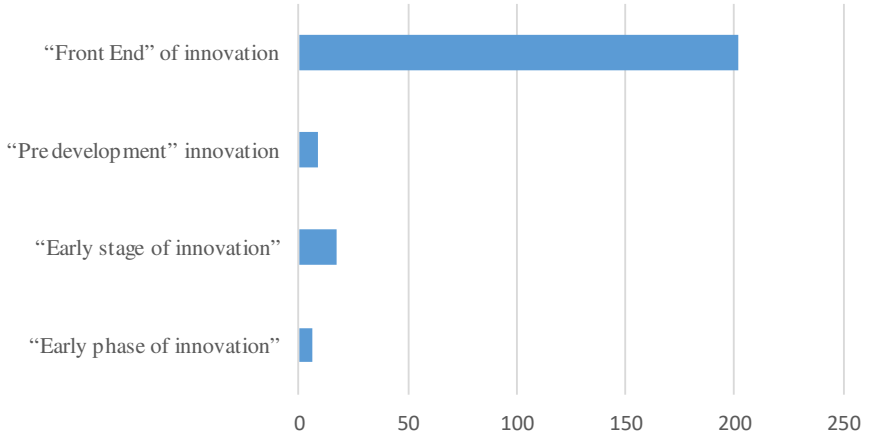

Figure 3-1 Results found concerning the possible nomenclatures to be used in the query.

The review classified the papers according to their contents and retained only those with topics pertaining to the FEI and published until 2015. Nonetheless, relevant works started to appear from 1995, an interesting fact as the term "Fuzzy Front End" was coined in 1991. In some papers, the expression "Front End (…) Innovation" was not related to the FEI but to other issues such as topics addressing the role of design, organisational Front-End activities, and Front-End engineering. Additionally, papers with no abstract or written in a language other than English were not considered. After the classification procedures, the final sample consisted of 169 titles.

3.1.2 Data analysis

The New Concept Development (NCD) Model by Koen et al. (2002) provides a theoretical framework to analyse the results of the integrative literature review. The PDMA ToolBook for New Product Development contains a chapter presenting the NCD, which indicates that this is a method accepted by the Product Development & Management Association (PDMA). Furthermore, the "Three Phase Front End Model" (Khurana and Rosenthal, 1997, 1998) offered an additional analytical perspective. This model provides a wide approach of the FEI processes and it has a compatible definition of "idea" and "opportunity" with the NCD Model.

The 169 articles were systematically organised according to their publication year, title, abstract and publication information. Moreover, the results were categorised based on the main

content of the paper, as depicted in their abstract. Each paper was assigned to a n-dimensional classification space featuring components of two frameworks: the "NCD Model"; and the "Three Phase Front End Model". Furthermore, one paper may contain more than one component, these cases were classified considering the dominant approach presented in the study. For example, a research publication on the "process of generating new-market disruptive innovation (NDI) ideas for products, driven by design and resources" would be classified as "Idea Generation and Enrichment" (IGE) in the "NCD Model" and as "Pre-phase Zero" (PP0) in the "The Three Phase Front End Model". However, due to their scope, they could have also been classified as "Organisational Capabilities" (OC) and "Product Development Organization" (PDO), respectively.

3.2 Research Methodological Procedures

The design-science (DS) paradigm seeks to extend the boundaries of human and organisational capabilities by creating new and innovative artefacts (Hevner et al., 2004). According to Simon (1997), engineering planning and design are part of the science of the artificial, and both deal with complex systems included in complex environments.

This research paradigm has a focus on 'utility', in other words, it is interested in the construction and evaluation of generic means–ends relations (Winter, 2008). Hence, "while theory building is important and necessary to explain real-world phenomena, this knowledge also needs to be put into action in order to solve real-world problems" Winter (2008, p. 472). Similarly, for Simon (1996) design is concerned with how things ought to be, with devising artefacts to attain goals.

The integrative literature review identified the need to offer a unifying and formal representation of the FEI domain. This need represents the core of the thesis and is translated by the following questions:

1) How can we build a comprehensive knowledge representation of the Front End of Innovation?

a) Which components would this FEI knowledge representation comprise?
b) Which would be the boundaries of this knowledge representation?

Considering these questions, the Design Science represents an adequate approach to develop an ontology for the FEI knowledge domain.

Table 3-1 Research Questions and its respective Methods describes the methods that were applied to each research question.

Table 3-1 Research Questions and its respective Methods and tools

Research Questions	Approaches
How can we build a comprehensive knowledge representation of the Front End of Innovation?	Literature review Design Science Ontology Development Exploratory Interviews Focus Group
Which components would this FEI knowledge representation comprise?	Literature review Design Science Ontology Development Exploratory Interviews
Which would be the boundaries of this knowledge representation	Design Science Literature Review Exploratory Interviews

These approaches listed in Table 3-1 made possible the answers to the research questions, hence Figure 3-2 illustrates the summarised ontology development process (phases), considering the Design Science Research Paradigm.

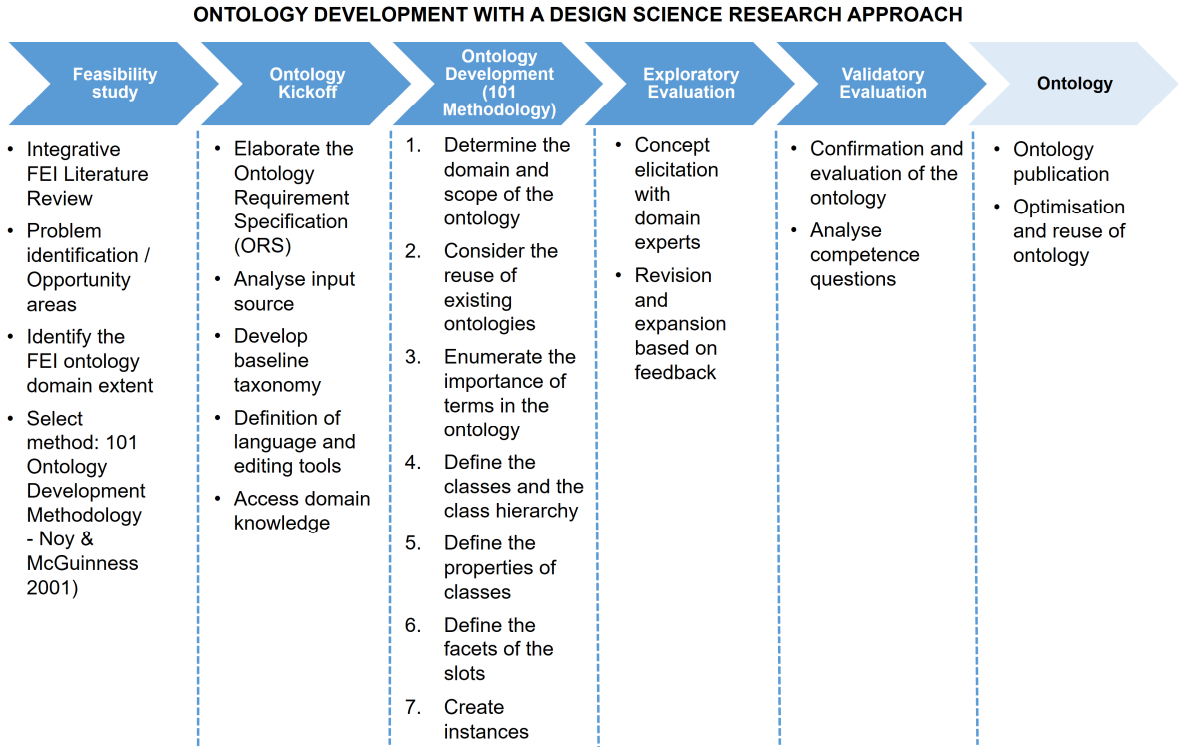

Figure 3-2 Summarised Ontology Development Process with DS adapted from (Staab, Studer, Schnurr, & Sure, 2001; Shi, Liu, Jing, Xiong, & Zhang, 2009 and Noy & McGuinness, 2001)

The Design Science Research Frameworks from Hevner et al. (2004) and March & Smith (1995) shaped the definition of the research activities and outputs. And for the ontology development, the 101 Ontology Development Methodology (Noy and McGuinness 2001) provided the seven steps to develop the FEI^{2}O, followed by a two-phase evaluation approach.

March and Smith (1995) propose a two-axes structure: research outputs (Construct, Method, Model and Instantiation) and research activities (Build, Evaluate, Theorise and Justify). This is a valuable contribution to understand the types of artefacts produced by the Information System Design Research. These are not isolated concepts but an interdependent system (Winter, 2008). Table 3-2 presents the concept definitions of the framework.

Table 3-2 Concepts definition

Concepts	Definition
Constructs	Constructs or concepts constitute a vocabulary of a domain. They comprise a conceptualization to describe problems within a domain.
Model	A model is a set of propositions or statements stating relationships among constructs.
Method	A method is a set of steps (it can be an algorithm or guideline) used to accomplish a task.
Instantiation	An instantiation is the fulfilment of an artefact in its environment. It operationalizes constructs, models and methods.

Adapted from Osterwalder (2004)

According to March and Smith (1995, p. 256), "the first dimension of the framework is based on design science research outputs or artefacts: constructs, models, methods and instantiations. The second dimension is based on broad types of design science and natural science research activities: build, evaluate, theorise, and justify". Therefore, it is a comprehensive approach suitable for the present research, as well as the Information Systems Research Framework, from Hevner et al. (2004).

The work "Design Science in Information System Research" (Hevner et al., 2004) also provides a conceptual framework for this study. The authors propose the Information Systems Research Framework, this representation provides guidelines for understanding, executing, and evaluating a design science research. Figure 3-3 presents a unifying and summarized research framework focused on the research outputs. The framework illustrated in Figure 3-3 combines the contribution of Hevner et al. (2004) and March & Smith (1995) and Table 3-3 presents a detailed specification of the content of research activities and outputs.

The following framework considers the environment and its relevance to the Information System Research while the knowledge base contributes to the formation of a rigorous analysis, therefore consisting of the utility approach from the DS. Chapter 2 of this thesis identified the knowledge base and characterised the environment. Chapter 4 addresses the ontology proposition that uncovers the business needs and knowledge application. Chapter 5 presents

the evaluation procedures consisting of a two-phase approach: an exploratory and a validation. Lastly, Chapter 6 presents a discussion of the ontology applications.

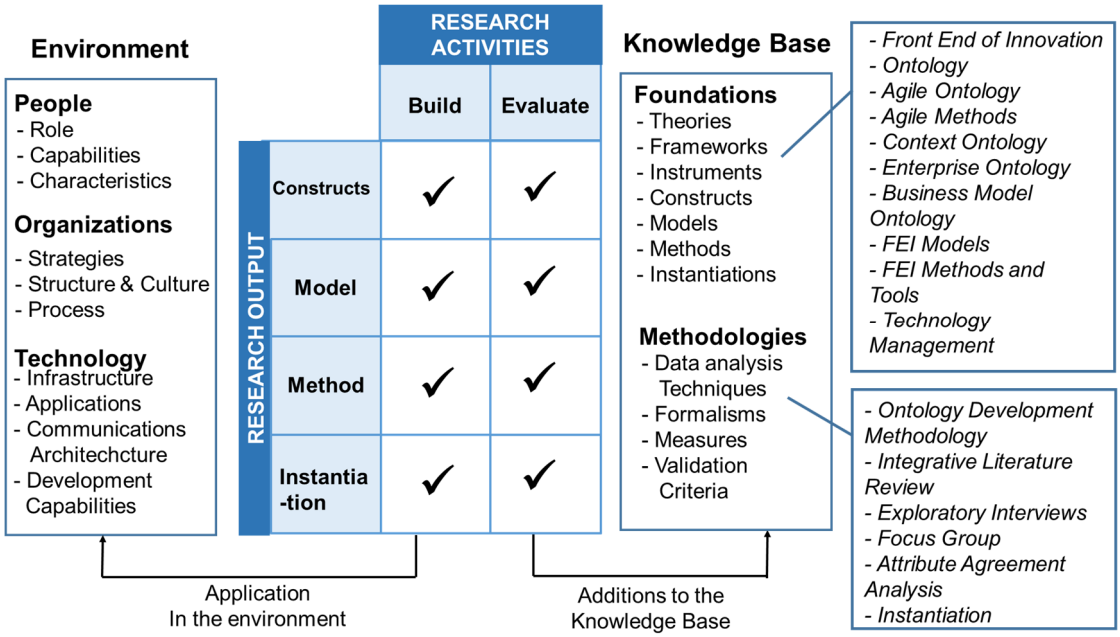

Figure 3-3 Summarised research framework focused on research outputs. Adapted from Hevner et al. (2004) and March & Smith (1995)

For March and Smith (1995), the DS results in constructs, models, methods, and implementations. Furthermore, it also needs a basic language of concepts (i.e., constructs), which is helpful to characterise a given phenomenon. These concepts/constructs can be combined in higher order constructions, for instance, by means of models to describe tasks, situations, or artefacts. Moreover, design scientists also develop methods, in other words, ways of performing goal-directed activities. The instantiation is the last component of the research outputs and it is responsible for performing certain tasks, for instance, to prove the utility of the model and/or method. Table 3-3 presents the content of the research activities and outputs considering the FEI^{2}O.

Table 3-3 Research organisation, adapted from March and Smith (1995)

		Research Activities			
		Build	**Evaluate**	**Theorise**	**Justify**
Research Outputs	**Constructs**	- An integrative ontology and its concepts for the Front End of Innovation Knowledge Domain	- Exploratory collaboration and concept elicitation with domain experts - Construction of a comprehensive scenario to demonstrate the ontology.	A common vocabulary (definitions) for the FEI concepts.	a) Evidence from the literature; b) Results obtained from the exploratory interviews; c) Results obtained from the validation phase.
	Model	- A comprehensive and integrative FEI model	Using qualitative and quantitative method validation criteria: a) Exploratory interviews; b) Focus Group; and, c) Attribute Agreement Analysis	Integration of the main FEI reference models and key concepts regarding the beginning of the innovation process.	a) Evidence from the literature; b) Results obtained from the exploratory interviews; c) Results obtained from the focus group.
	Methods	- A comprehensive set of sub-ontologies organised according to key FEI drivers. - A holistic teaching perspective for the FEI.	- According to the FEI literature analysis. - Revision and expansion based on feedback. - Analysis of the competence questions.	-	-
	Instantiation	- The artefact: The Front End of Innovation Integrative Ontology	Applicability of the artefact. Further research and tests. (chapter 7)	-	-

The following list presents the research outputs of the Front End of Innovation Integrative Ontology (FEI^{2}O).

a) Constructs: The FEI^{2}O addresses a total of 98 FEI concepts. A list of these concepts as well as their definitions is available in the Glossary of Appendix C. This comprehensive work provides a common language to this knowledge domain.
b) Model: The FEI^{2}O is a comprehensive and integrative model as well as a formal domain reference model.
c) Method: The FEI^{2}O provides a set of sub-ontologies organised according to key FEI drivers. A method is a set of steps used to accomplish a task (see Table 3-2 Concepts definition, p. 85). Consequently, the processes comprised in the FEI^{2}O represent ways of performing goal-directed activities.
d) Instantiation: Chapter 6 provides two instantiation cases. These instantiations are helpful to evidence the utility of the FEI^{2}O.

The theorise and justify outputs received less attention in detriment of the build and evaluate concepts, however the predominant focus on build and evaluate is a characteristic of the DS. For March and Smith (1995), DS consists mainly of Build and Evaluate activities, illustrated by the first two columns of Table 3-3. The research activities from this study relate to the construction of an artefact with the specific purpose of formalising the FEI knowledge domain. They refer to the construction of a model, its constructs and instantiations. The evaluation determines the quality of operation, efficiency and usefulness of the produced artefact. The evaluation procedures are explored in section 3.4.

3.3 Ontology Development

The first step of the 101 Ontology Development Methodology concerned the definition of the domain and scope of the proposed ontology. The domain concerns the representation of the initial phase of the innovation process and its scope is outlined according to the so-called competence questions (see Table 3-4).

The first step also benefited from the definition of the Ontology Requirements Specifications (ORS) (Suárez-Figueroa et al., 2009). Requirements in most of the cases are written in natural language (Zavoral, Jung, & Bădică, 2014). A vital property of a requirement is that it should be communicable. The ORS is a valuable tool to develop an ontology, as it provides precise

guidelines for searching available knowledge resources to be reused in the ontology development as well as to evaluate the ontology content (Suárez-Figueroa et al., 2011). Hence, Table 3-4 Ontology Requirements Specifications (ORS) of the FEI Integrative Ontology shows a summarised view of the Ontology Requirements Specification as well as the Competence Questions. Both aspects represent vital steps toward engineering the ontology.

Table 3-4 Ontology Requirements Specifications (ORS) of the FEI Integrative Ontology (FEI^2O)

Ontology Requirements Specifications – ORS
1. Identify purpose
The main goal of this ontology is to provide an integrative and formal domain model for the Front End of Innovation.
2. Identify scope
The FEI^2O covers purposes, roles, processes, activities, strategy and portfolio planning, facilities and actors situated along the FEI process, from the opportunity discovery until the concept definition. The level of granularity of the FEI^2O directly concerns the competence questions and the identified terms.
3. Identify Implementation Language
The Unified Modelling Language is a formal approach for representing ontologies; this is a subset of the Object Management Group's Unified Modelling Language (UML) (Cranefield, Haustein, & Purvis, 2001). Moreover, it can be used for writing software blueprints as well as to visualise, specify, build and document an object oriented system (Wang & Chan, 2001). The ontology uses the UML class diagram language. Therefore, this language provided an enhanced representation and understanding of the underlying concepts. Appendix B presents a quick guide to the UML notation.
4. Identify intended end-users
User 1: Entrepreneurs User 2: FEI practitioners. User 3: FEI scholars. User 4: R&D groups. User 5: Technology Transfer Offices. User 6: Venture Capital Firms. User 7: Business Angels. User 8: Educational institutions responsible for teaching innovation and entrepreneurship.

5. Identify intended uses
Use 1: A comprehensive formal knowledge model to comprehensively and integrative represent the Front End of Innovation. Use 2: A formal reference model capable of providing a common language for the FEI. Use 3: A conceptual model suitable to guide the intended end-users in the process of developing a concept. Use 4: A holistic teaching perspective to the FEI.
6. Identify requirements
a. Non-functional requirements
The terminology to be used in the ontology follows: The reuse of existing ontologies: Enterprise Ontology, Context Ontology; Agile Ontology; and, Business Model Ontology. The literature: the construction of the FEI key terms is based on the literature related to the predevelopment phase of the innovation process.
b. Functional Requirements: Groups of Competence Questions
CQ1. Does the ontology allow the identification of the knowledge domains present in the FEI? CQ2. Which are the outcomes (results) of the Ontology? CQ3. Which processes unfold in the context of the Ontology? CQ4. Which are the stages related to the new concept development? CQ5. Which are the outputs of the FEI Agile New Concept Development? CQ6. Who are the actors in the FEI? CQ7. Which are the roles played by FEI actors?

Template adapted from (Suárez-Figueroa et al., 2009; Noy & McGuinness, 2001)

For the FEI^{2}O, the ORS enabled the identification of: The Purpose of the artefact; the Scope; The Implementation Language; the Intended End-Users; the Intended Uses; and Requirements (Functional and Non-Functional) (see Table 3-4). Furthermore, the scope of the Integrative FEI Ontology was defined considering the need to establish the boundaries of the work. Considerable analysis has been dedicated to deciding these limits as well as which existing ontologies could be used.

Many factors influenced the choice of terms of the ontology. However, the most important were the analysis of the main FEI models and of the significance of the concepts to the FEI Integrative Ontology – considering both the specialised literature and the elicitation of the terms by experts from the field. Moreover, it was implemented the partial reuse of some ontologies.

According to the 101 Methodology (Noy and McGuinness, 2001), the ontology development consisted of the following steps:

1) The first step outlines the domain and scope of the ontology by defining the competence questions. Moreover, the integrative literature review performed an in-depth analysis of the main FEI reference models. This review lead to a matrix consisting of the authors position with respect to Opportunity; Idea and Concept Development; Influencing Factors; the applicability of Gates; Strategy; their approach to the Flow of Activities; their definition of FEI Roles; and, the Innovation Spectrum of the works.
2) The second step suggests the reuse of existing ontologies. This work implements contributions from the Context Ontology (CO), Enterprise Ontology (EO), Business Model Ontology (BMO) and Agile Ontology (AO).

The third to the sixth step organise the terms in the ontology.

3) The third step enumerated important terms in the ontology;
4) The fourth step defined the classes and the class hierarchy;
5) The fifth step defined the properties of classes; and,
6) The sixth defined the facets of the slots.

Between steps 6 and 7 lies the evaluation process explored in the next section. The last step concerns the creation of instances (see Chapter 6, section 6.3 p. 159). This step is necessary to demonstrate the utility of the artefact.

Lastly, the data triangulation was obtained by analysing the FEI literature and the applicability of reusable ontologies against Interviews and Focus Group as tools to elucidate and validate the artefact developed.

3.4 Ontology Evaluation Methodological Procedures

The methodological procedures to evaluate the ontology consisted of a two-phase approach, an exploratory and a validation phase.

The Exploratory Phase was carried out from June/2016 until May/2017. It was performed a total of 18 interviews with 14 participants; this was responsible for the concept elicitation by domain experts. Therefore, this phase contributed to the enrichment and refinement of the proposed artefact.

Furthermore, the evaluation process advanced for the next phase only after reaching data saturation, considering data saturation as the point where no additional new information was proposed (Fusch & Ness, 2015). Chapter 5, Section 5.1 Exploratory Phase (see p. 128) provides the participant's profiles and specifies their contributions.

The Validation Phase was responsible for the final evaluation of the artefact by means of a Focus Group. It gathered nine participants of which seven were present physically and two virtually. One of the virtual attendees provided her evaluation passed the deadline of the session and her answers were not included in the results. Solely, the answers provided by the participant during the Focus Group session were considered valid. No changes or late submissions were allowed to ensure a homogeneous treatment for all the data. This protocol helped to avoid potential future misunderstandings due to participants forgetting the content under evaluation.

Therefore, the eight acceptable results were analysed according to an Attribute Agreement Method; the results are available in Chapter 5, section 5.2.2 Results (see p. 134).

The Validation Phase relied on the use of defined criteria to evaluate the ontology. The literature suggests a diversity of criteria and Table 3-5 illustrate them according to each author.

Table 3-5 Criteria to evaluate ontologies

Author	Criteria
Hevner (2004)	Functionality, Completeness, Consistency, Accuracy, Performance, Reliability, Usability, Fit with the organisation
March and Smith (1995)	Completeness, Simplicity, Elegance, Understandability, Ease of use
Holsapple & Joshi (2002)	Comprehensives, Correctness, Conciseness, Clarity, Utility

The choice and number of criteria to evaluate an ontology depend on the subject and artefact. Some studies chose five criteria to evaluate their work (Bullinger, 2008; Hosapple and Joshi, 2002). Similarly, this study also selected five criteria: Completeness; Comprehensiveness; Utility; Consistency and Understandability. This selection followed the characteristics of both the FEI knowledge domain and the proposed ontology.

Finally, the ontology was also evaluated against the competence questions. The analysis consisted of a Focus Group session in which the participants assessed whether the ontology provided answers to the competence questions.

3.5 Conclusions

The creation of the ontology relied on the Design Science Research Paradigm and with the support of the 101 Ontology Methodology Development (Noy and McGuinness, 2001). Figure 3-4 presents a graphic overview of the organisation of the work. This representation provides a summarised view of the correlation of each of the sections of this thesis with the corresponding Methodological Design Science Phase.

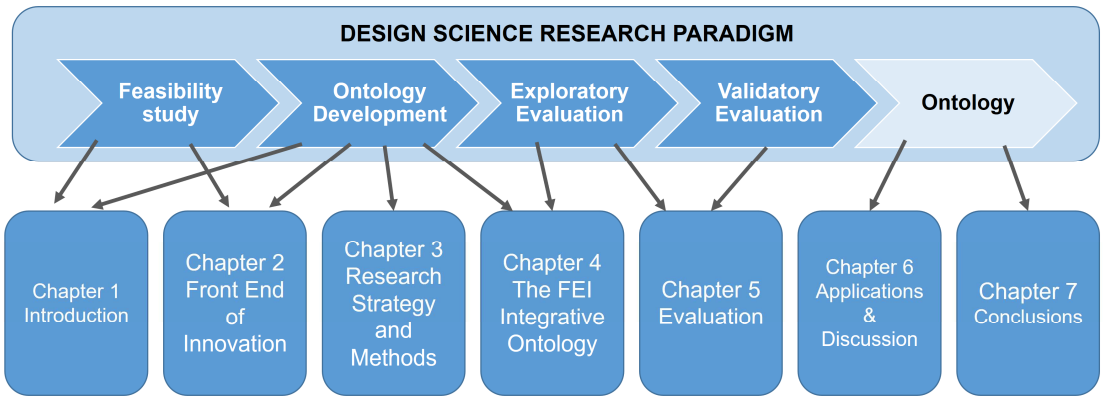

Figure 3-4 Summarised research methodological development of this thesis

This chapter presented the methodological choices and procedures adopted to conduct this thesis. The aim was to apply effective research methods for all research phases, as the

appropriate design and use of research methods are key components to build a strong scientific foundation.

The DS offered an adequate research strategy fit to develop the FEI^{2}O, as this approach attempts to create things that serve human purposes and it is technology-oriented (March & Smith, 1995).

This multi-method approach, qualitative and quantitative, has the benefit of protecting against and correcting for inherent methodological biases either for or against certain types of theories (Brewer and Hunter, 1989).

Chapter 4 The FEI Integrative Ontology

After nearly 24 years[6], there is still no widely comprehensive accepted model or ontology, which covers the large scope of the Front End of Innovation. Several concepts and their relationship lack attention in the realm of an integrative knowledge representation of the FEI, for instance: opportunity identification, opportunity assessment/analysis, opportunity timing, adjoining disciplines of research & development (R&D), technology management and other interrelated activities.

The present work addresses some of these research demands, namely the need for developing an ontological approach to the adjoining disciplines of R&D and technology management (Bullinger, 2008).

The FEI^{2}O offers a conceptual approach encompassing the definitions of technology, which is a broad concept that represents a means to accomplish a certain end (Eckhardt, 2013). As technological refers to an adjective of technology, a definition of this word is valuable to enlighten the understanding of technological innovations. According to the Merriam-Webster Dictionary (2017), technology refers to:

> *1 a: the practical application of knowledge especially in a particular area: engineering 2 - medical technology*
> *b: a capability given by the practical application of knowledge a car's fuel-saving technology*
> *2: a manner of accomplishing a task especially using technical processes, methods, or knowledge new technologies for information storage*
> *3: the specialized aspects of a particular field of endeavor educational technology*

[6] The term Fuzzy Front End – FFE was made popular by Smith and Reinertsen in a work published in 1991 (Khurana and Rosenthal, 1997; Reid and De Brentani, 2004; Verworn et al., 2008).

Therefore, technological innovations refer to "new products and processes and significant technological changes of products and processes" OECD (2013, glossary of terms). In other words, the general coverage of the FEI^{2}O was conceptually designed to enable the development of a New Concept considering a regular set of fields.

The FEI Integrative Ontology (FEI^{2}O) is grounded in a set of six sub-ontologies, which are the FEI High-Level; the FEI Purpose; the FEI Stage; Portfolio Planning & Management; the FEI Agile New Concept Development; and, the FEI Actors. These subontologies formalise core aspects related to the FEI. The high-level sub-ontology depicts the interdomain key relationships of the FEI^{2}O core concepts. Lastly, the FEI^{2}O can give rise to a preliminary FEI^{2}O Canvas, a by-product contribution of the work.

The FEI may be understood as the foundation for future product development activities. Therefore, the decisions carried out in this pre-development phase determine the innovation options that will be available for further development and commercialisation (Koen, Bertels, & Kleinschmidt, 2014). In sum, the FEI addresses crucial activities, processes, organisational factors, roles and responsibilities dealt within the proposed ontology. Figure 4-1 – illustrates the FEI Ontology Composition.

Figure 4-1 FEI Ontology Composition

The literature strongly recommends the reuse of concepts to which the FEI^{2}O abided. As such, this thesis identifies the reusable concepts from existing ontologies and presents them together with the acronym of their respective ontology.

Table 4-1 lists the acronyms of the ontologies whose concepts were reused. Other relevant information, for reading this thesis, concerns the capital letters throughout the work. This notation emphasises ontology concepts. Text in bold refers to the properties of the ontology. Lastly, the boxes in this chapter present the ontology description in natural language.

Table 4-1 List of acronyms used in the FEI^{2}O

Acronyms	**Stands for**
CO	Context Ontology
EO	Enterprise Ontology
BMO	Business Model Ontology
AO	Agile Ontology

The next sections present each of the six sub-ontologies that compose the FEI^{2}O (Front End of Innovation Integrative Ontology).

4.1 The Sub-Ontology FEI Purpose

The key role played by the concept Opportunity demands a special emphasis, hence Figure 4-2 presents the sub-ontology FEI Purpose focused on the OPPORTUNITY Class while Figure 4-3 portrays the entire sub-ontology, including the OPPORTUNITY Class with its relations. Moreover, Figure 4-2 shows the sources of innovation, which account for internal and external sources of opportunities. The potential for innovation may be found in more than one area at a time (Drucker, 2002). Therefore, both internal and external are sources of opportunity that:

- Enable the Recognition of an Opportunity. It represents early and frequently uncertain technology and market assessments, which will guide the beginning of the decision-making process in the FEI (Koen et al., 2002); and,

- Feed Confidence, which entails the actor individual's evaluation of external enablers and/or New Venture Ideas (Davidsson, 2015).

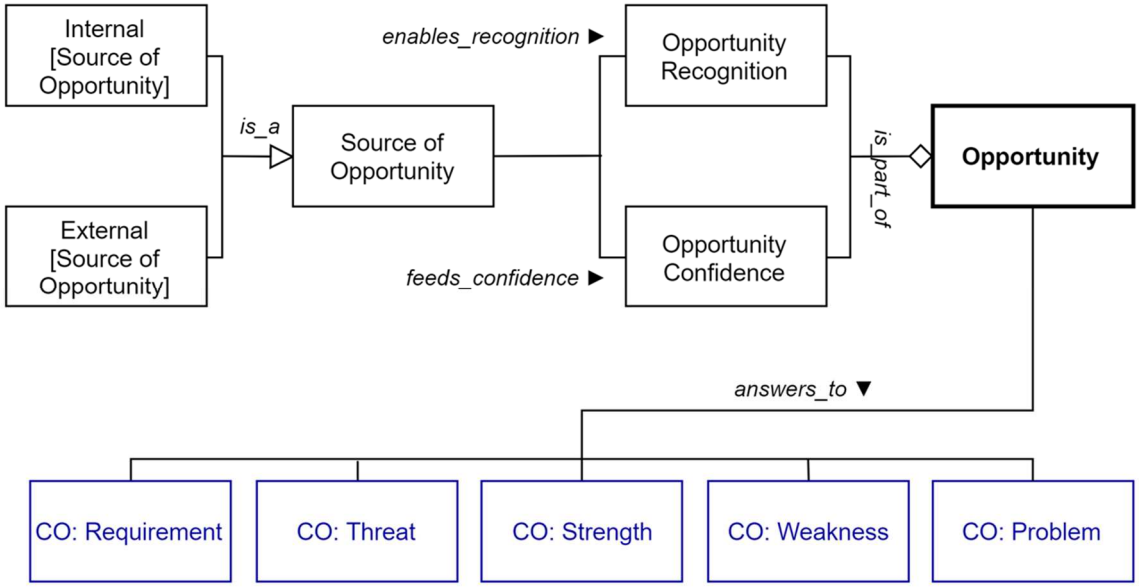

Figure 4-2 Sub-ontology FEI Purpose, focus on Opportunity

An alternative approach for reading the ontology is the use of natural language. Therefore, Box 4-1 provides a description of the Sub-ontology FEI Purpose with a focus on the Opportunity concept.

Box 4-1 – Description in natural language of the Sub-ontology FEI Purpose, focus on Opportunity

INTERNAL [SOURCE OF OPPORTUNITY] **is_a** SOURCE OF OPPORTUNITY
EXTERNAL [SOURCE OF OPPORTUNITY] **is_a** SOURCE OF OPPORTUNITY
SOURCE OF OPPORTUNITY **enables_recognition** OPPORTUNITY RECOGNITION
SOURCE OF OPPORTUNITY **feeds_confidence** OPPORTUNITY CONFIDENCE
OPPORTUNITY RECOGNITION **is_part_of** OPPORTUNITY
OPPORTUNITY CONFIDENCE **is_part_of** OPPORTUNITY
OPPORTUNITY **answers_to** CO: REQUIREMENT
OPPORTUNITY **answers_to** CO: THREAT
OPPORTUNITY **answers_to** CO: STRENGTH
OPPORTUNITY **answers_to** CO: WEAKNESS
OPPORTUNITY **answers_to** CO: PROBLEM

As illustrated in Figure 4-2 and Box 4-1, RECOGNITION OF AN OPPORTUNITY and OPPORTUNITY CONFIDENCE are components of the OPPORTUNITY. Opportunity is a "business or technology gap, that a company or individual realizes, that exists between the current situation and an envisioned future in order to capture competitive advantage, respond to a threat, solve a problem, or ameliorate a difficulty" (Koen et al., 2002, p. 7). Even more, an OPPORTUNITY may respond to:

- CO: REQUIREMENTS – something that is necessary and needed (Leppänen, 2005); in other words, something indispensable to achieve a purpose.
- CO: THREAT – situation or condition that is a risk for attainment of a goal (Leppänen, 2005).
- CO: STRENGTH – something in which one is good, something that is regarded as an advantage and thus increasing the possibilities to gain something better (Leppänen, 2005).
- CO: WEAKNESS – something in which one is poor, something that could or should be improved or avoided (Leppänen, 2005).
- CO: PROBLEM – the distance or a mismatch between the prevailing state and the state reflected by the goal. They are the point of departure and the major source of New Venture Ideas, Goldkuhl et al. (1998); Jayaratna, (1994) apud Leppänen, (2005) (Wimmer, 2016).

Figure 4-3 demonstrates the relationship between OPPORTUNITY and the other concepts addressed in the FEI Purpose. It is necessary to emphasise the key role of OPPORTUNITY and the FEI EO: STRATEGIC PURPOSE, considering that the first **drives strategic purpose.**

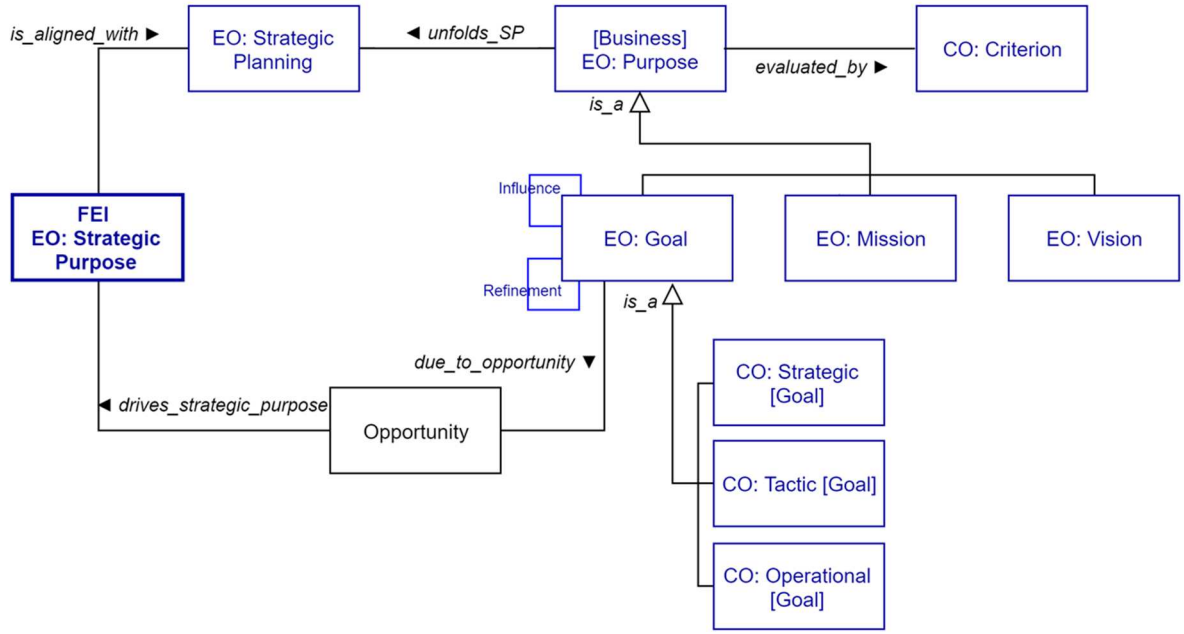

Figure 4-3 Sub-ontology FEI Purpose

Box 4-2 offers the description of the Sub-ontology FEI Purpose. Additionally, the next paragraphs explore the representation of the content addressed in this sub-ontology.

Box 4-2 – Description in natural language of the Sub-ontology FEI Purpose

FEI EO: STRATEGIC PURPOSE **is_aligned_with** EO: STRATEGIC PLANNING
[BUSINESS] EO: PURPOSE **unfolds_sp** EO: STRATEGIC PLANNING
[BUSINESS] EO: PURPOSE **evaluated by** CO: CRITERION
EO: GOAL **due_to_opportunitu** OPPORTUNITY
OPPORTUNITY **drives_strategic_purpose** FEI EO: STRATEGIC PURPOSE
EO: GOAL **is_a** [BUSINESS]EO: PURPOSE
EO: MISSION **is_a** [BUSINESS]EO: PURPOSE
EO: VISION **is_a** [BUSINESS]EO: PURPOSE
CO: STRATEGIC [GOAL] **is_a** EO: GOAL
CO: TACTIC [GOAL] **is_a** EO: GOAL
CO: OPERATIONAL [GOAL] **is_a** EO: GOAL

The FEI EO: STRATEGIC PURPOSE consists of a purpose, held by an actor, of "strategic" importance (Uschold, King, Moralee, & Zorgios, 1998). It is expected to be aligned with the EO: STRATEGIC PLANNING of the organisation. This Strategic Planning was unfolded by

the [BUSINESS] EO: PURPOSE that envisioned a reason for executing an activity. It denotes something that an Organisation Unit can be responsible for (Uschold et al., 1998), in this case it could be the FEI management.

To ensure an adequate replication of the reality, the model considers both situations of FORMAL and INFORMAL organisations. Similarly, [BUSINESS] EO: PURPOSE and FEI EO: STRATEGIC PURPOSE represents concepts possible to be found as FORMAL and INFORMAL.

The [BUSINESS] EO: PURPOSE may be evaluated according to some CO: CRITERION, defined as "a standard of judgment presented as an established rule or principle for evaluating some thing" (Leppänen, 2005, p. 171).

These criteria for decision are specially important because EO: GOAL, EO: MISSION and EO: VISION are types of Purposes (Uschold et. al, 1998), which may or may not be objectives. Moreover, they may be further specialised according to their support to achieve organisational purposes, due to their measurability and their time horizon. These concepts are likely to happen in varying degrees. For instance:

- The level of contribution to achieve a purpose, from lowest to highest level: GOAL, MISSION, VISION.
- The measurability, from most to least measurable: GOAL, MISSION, VISION.
- The time horizon, from shortest to highest: GOAL, MISSION, VISION.

The concept EO: GOAL has two reflexive relations, **Influence** and **Refinement**, illustrated in Figure 4-3. They represent that a given “n” instance of a goal may be subject to a refinement or an adjustment due to some influences from other goals. Goal types are:

- CO: STRATEGIC GOAL – regards a pattern in a stream of decision (Mintzberg, 1978).
- CO: TACTIC GOALS – show the manner by which to attain strategic goals (Leppänen, 2005).
- CO: OPERATIONAL GOAL – generally determined by concrete requirements that are to be fulfilled by a specific point in time (Leppänen, 2005).

Moreover, a CO: GOAL is expected to happen due to an OPPORTUNITY. Considering the vital role played by the OPPORTUNITY, this concept will drive the FEI EO: STRATEGIC PURPOSE.

4.2 The Sub-Ontology Portfolio Planning & Management

The sub-ontology Portfolio Planning & Management (PPM) was designed because a well-planned portfolio is one precondition to have a foundation for streams of successful new products (Khurana and Rosenthal, 1997). PROJECT PORTFOLIO MANAGEMENT can be described as a dynamic process in which the portfolio of active projects is subject to a periodic review and update. Moreover, it supports the evaluation, selection, prioritisation and control of the firm's project portfolio (Oliveira and Rozenfeld, 2010). The PPM comprises a portfolio of new products, product strategy and organisational factors, which, according to Khurana and Rosenthal (1997), are elements responsible for providing a successful New Product Development.

According to the literature, successful organisations create a holistic view of the front end, with senior management and core teams (elements present in this sub-ontology – see Figure 4-7 p. 108):

> *Adopting a process-oriented style of work to deliberately link a wide range of technical and organizational considerations concerning business strategy, product decisions, and the subsequent product development project. Here, special efforts, through well-defined executive reviews and core teams roles, and formal processes, are required to help ensure that product strategy becomes integrated with business strategy and resource planning (Khurana & Rosenthal, 1998, p. 58)*

Therefore, the PP&M comprises a portfolio of new products, product strategy and organisational factors, which, according to Khurana and Rosenthal (1997), are elements

responsible for providing a successful New Product Development. This sub-ontology is presented in Figure 4-4:

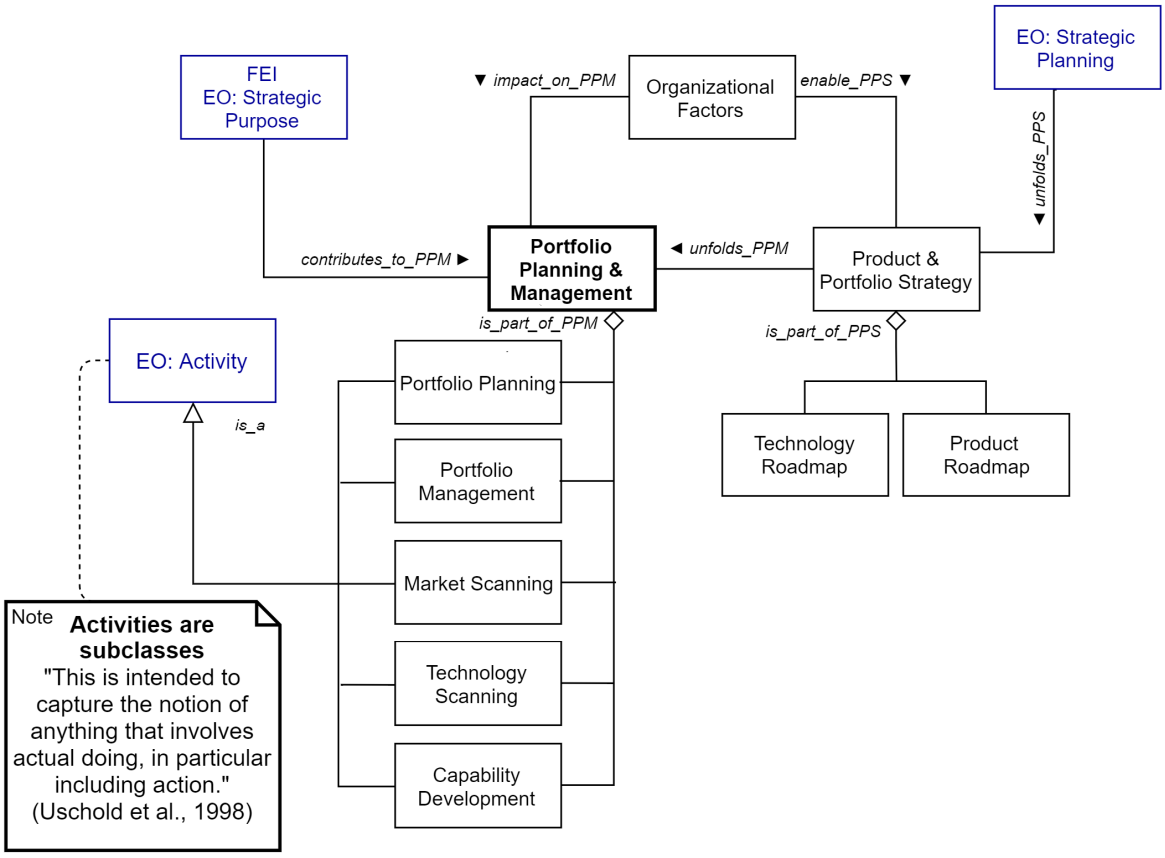

Figure 4-4 Sub-ontology FEI Portfolio Planning & Management

Box 4-3 provides an additional representation of the Sub-ontology FEI Portfolio Planning & Management. The next paragraphs further explore the content of this sub-ontology.

Box 4-3 – Description in natural language of the Sub-ontology FEI PP&M

EO: FEI STRATEGIC PURPOSE **contributes_to_PPM** PORTFOLIO PLANNING & MANAGEMENT

EO: STRATEGIC PLANNING **unfolds_PPS** PRODUCT & PORTFOLIO STRATEGY

PRODUCT AND PORTFOLIO STRATEGY **unfolds_PPM** PORTFOLIO PLANNING & MANAGEMENT

ORGANIZATIONAL FACTORS **enable_PPS** PRODUCT & PORTFOLIO STRATEGY

ORGANIZATIONAL FACTORS **impact_on_PPM** PORTFOLIO PLANNING & MANAGEMENT

PORTFOLIO PLANNING **is_part_of_PPM** PORTFOLIO PLANNING & MANAGEMENT

PORTFOLIO MANAGEMENT **is_part_of_PPM** PORTFOLIO PLANNING & MANAGEMENT
MARKET SCANNING **is_part_of_PPM** PORTFOLIO PLANNING & MANAGEMENT
TECHNOLOGY SCANNING **is_part_of_PPM** PORTFOLIO PLANNING & MANAGEMENT
CAPABILITY DEVELOPMENT **is_part_of_PPM** PORTFOLIO PLANNING & MANAGEMENT
PORTFOLIO PLANNING **is_a** ACTIVITY
PORTFOLIO MANAGEMENT **is_a** ACTIVITY
MARKET SCANNING **is_a** ACTIVITY
TECHNOLOGY SCANNING **is_a** ACTIVITY
CAPABILITY DEVELOPMENT **is_a** ACTIVITY
TECHNOLOGY ROADMAP **is_part_of_PPS** PRODUCT & PORTFOLIO STRATEGY
PRODUCT ROADMAP **is_part_of_PPS** PRODUCT & PORTFOLIO STRATEGY

The FEI EO: STRATEGIC PURPOSE will contribute to the PP&M, considering that the PP&M comprises:

- The PORTFOLIO PLANNING processes needs, collects and analyses internal and external information related to markets and technologies of interest to the firm/start-up (Patterson, 2007, p. 49).
- The PORTFOLIO MANAGEMENT concerns a set of activities including portfolio assessment, resource management, and portfolio review (Patterson, 2007).
- The MARKET SCANNING makes companies aware of market opportunities (explicit and tacit), considering the context within industries that the firms operate. Moreover, it facilitates finding new opportunities outside the market segments currently on focus (Alam, Guild, & Sparkes, 2013).
- The TECHNOLOGY SCANNING refers to the function of making a firm aware of technological opportunities, which can be acquired or licensed from outside the firm. Moreover, it considers the company knowledge to develop the technology internally. Technology-scanning enables the discovery of a technological solution to an identified or anticipated customer problem (Alam et al., 2013).

- The CAPABILITY DEVELOPMENT addresses the capabilities that a firm owns together with the capability gaps that need to be satisfied (Osterwalder et al., 2004).

The EO: STRATEGIC PLANNING refers to a planning activity with the purpose to produce a strategy (Uschold et al., 1998). It also has a fundamental role in the unfolding of the PRODUCT & PORTFOLIO STRATEGY(P&PS). For the FEI^{2}O, Strategy may be FORMAL, as defined in an enterprise plan, and INFORMAL, as a preliminary hypothesis or an empirical initiative. A study with 126 Dutch firms (Langerak, Hultink, & Henrys, 2004) found that strategic planning and idea generation are positively related to new product performance, which in itself is positively related to organisational performance.

The literature reports studies from USA, Japanese and Dutch companies that exemplifies the importance of PORTFOLIO PLANNING & MANAGEMENT, PRODUCT & PORTFOLIO STRATEGY and ORGANIZATIONAL FACTORS (Khurana & Rosenthal, 1997; Koen et al., 2014a, 2014b; Langerak et al., 2004). Due to the FEI nature, one especial emphasis is necessary on projects emerging from the FEI, as they fill a portfolio of a company. The portfolio is a function of FEI activities rather than exclusively a function of Strategic Planning (Markham et al., 2010). This argument validates the necessary alignment between PP&M and P&PS supported by the FEI^{2}O.

The P&PS concerns the alignment between PP&M and P&PS and it is expected to enhance the articulation of core PP&M activities and Strategy (Khurana and Rosenthal, 1997). The P&PS comprises:

- TECHNOLOGY ROADMAP: The TRM is a method that "serves to describe the market, to plan product and process development, to establish technological capacities and to analyse resources (Willyar and McClees, 1987) apud (Oliveira and Rozenfeld, 2007)."
- PRODUCT ROADMAP: The Product Roadmap is a marketing function while Technology Roadmap planning is an R&D responsibility. "At various points in the

> process, these two functions should come together to share and integrate what they have learned. The resulting product roadmap will thus be responsive to R&D's understanding of technology developments, and technology strategies will reflect the firm's knowledge of current and future market factors (Patterson, 2007, p. 49)."

Some Organisational factors are highlighted in the literature as essential for a successful FEI. Therefore, considering that the ORGANISATIONAL FACTORS are essential to the PP&M and the P&PS, they are explored in detail from Figure 4-5 until Figure 4-7.

A study with 197 large US-based companies over a three-year period (Koen et al, 2014; 2014b) identified the attributes with the greatest importance to front-end performance. They are: Senior Management Commitment, Vision, Strategy, Resources, and Culture. The second part of this study identified that other organisational attributes with a minor degree of contribution, but still representative to the FEI Success include effective teams, team leadership, and communities of practice. The sub-ontology Portfolio Planning & Management addresses the Strategy while the other attributes were considered by the FEI^{2}O as organisational factors, due to their necessary alignment with the PP&M.

Organisational capabilities are helpful to determine whether and how opportunities are identified and analysed, how to manage the ideation phase, and how concepts and technologies are developed (Koen et al., 2002). Figure 4-5 presents the first excerpt of the Organisational Factors, namely the RESOURCES concept.

The construct BMO: RESOURCES is an important class as it comprises (Grant, 1991 apud Osterwalder, 2004; The authors, 2016):

- TANGIBLE ASSETS correspond to a physical asset, which its value can be measured. "Tangible resources include plants, equipment and cash reserves."
- INTANGIBLE ASSETS are assets that an entrepreneurs or company has, but it is not material, examples include: "patents, copyrights, reputation, brands and trade secrets."
- PEOPLE BASED SKILL is the notion that human resources are the people a firm needs to create value with tangible and intangible resources.

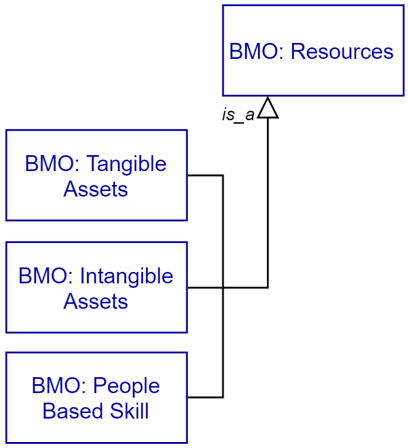

Figure 4-5 Sub-ontology FEI Portfolio Planning & Management focus on Organisational Factors [Resources]

Examples of Tangible Resources are properties, plants, machinery and equipment, material assets and cash reserves while Intangible Resources could be corporative reputation, organisational competences, patents, copyrights and trade secrets. Moreover, people based skills are those actors who contribute to the company business.

The creativity component is something embodied by a person, considering that the level of creativity that a person produces at any given point in time is a function of the creativity components operating, at that time, within and around that person (Amabile, 2012). Therefore, the ontology does not state a class for creativity, as it is included in the concept PEOPLE BASED SKILL or any FEI EO: ACTOR.

Figure 4-7 depicts the BMO: RESOURCES concept with its relations. Furthermore, RESOURCES **aggregate capabilities** BMO: CAPABILITY. The latter is the ability to perform a repeatable pattern of actions, which is necessary for the purpose of creating value for the customer while the former represents the means, which a company use to create value (Osterwalder, 2004). As a company may not have a given BMO: CAPABILITY, this Capability **may be provided by** the BMO: PARTNERSHIP. The latter is a voluntarily initiated agreement, developed by two or more independent companies, to develop a project or specific activity cooperatively, by coordinating the necessary capabilities, resources and activities (Osterwalder, 2004).

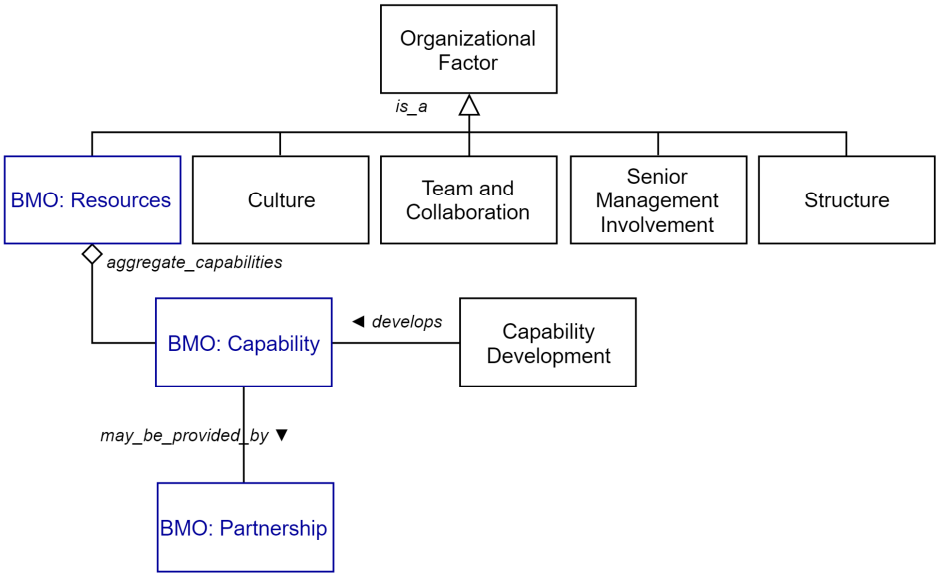

Figure 4-6 Sub-ontology FEI Portfolio Planning & Management focus on Resources [BMO: Capability]

The CAPABILITY DEVELOPMENT addresses the capabilities that a firm owns despite the capability gaps that need to be satisfied to provide higher value (Osterwalder et al., 2004). Therefore, the CAPABILITY DEVELOPMENT has as relation "**develops** BMO: CAPABILITY". The organisational factors comprehend vital contributors to the FEI success, therefore, Figure 4-7 gives a full representation of this concept.

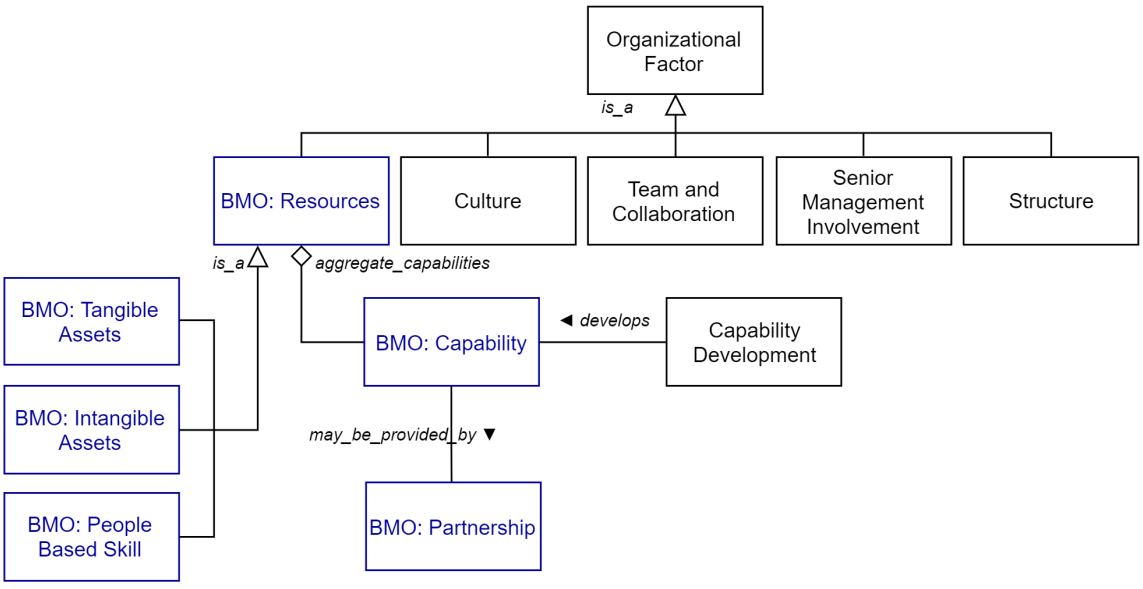

Figure 4-7 Sub-ontology FEI Portfolio Planning & Management Organisational Factors

Therefore, a complete view of the ORGANISATIONAL FACTORS involves:

- RESOURCES are the means that a company use to create value (Osterwalder et al., 2004).
- CULTURE is regarded as the "patterns of behavior, attitudes, and feelings within an organization". (Koen et al., 2014, p. 40).
- TEAM AND COLLABORATION can be exemplified by the following constructs: effective teams, team leadership and Communities of Practice (CoPs) (Koen et al., 2014).
- SENIOR MANAGEMENT INVOLVEMENT represents the degree of involvement of senior managers with front-end activities (Koen et al., 2014), and
- STRUCTURE facilitates the product development. In this regard, it is necessary to consider the flow of communication and a cross-functional sharing of responsibilities to become effective (Khurana and Rosenthal, 1997).

Box 4-4 offers a comprehensive representation of the organisational factors, which consists of an excerpt of Sub-ontology FEI Portfolio Planning & Management.

Box 4-4 – Description in natural language of the Organisational Factors

BMO: RESOURCES **is_a** ORGANIZATIONAL FACTOR
CULTURE **is_a** ORGANIZATIONAL FACTOR
TEAM AND COLLABORATION **is_a** ORGANIZATIONAL FACTOR
SENIOR MANAGEMENT INVOLVEMENT **is_a** ORGANIZATIONAL FACTOR
STRUCTURE **is_a** ORGANIZATIONAL FACTOR
BMO: TANGIBLE ASSETS **is_a** BMO: RESOURCES
BMO: INTANGIBLE ASSETS **is_a** BMO: RESOURCES
BMO: PEOPLE BASED SKILLS **is_a** BMO: RESOURCES
BMO: RESOURCES **aggregate_capabilities** BMO: CAPABILITY
CAPABILITY DEVELOPMENT **may_be_provided_by** BMO: PARTNERSHIP
CAPABILITY DEVELOPMENT **develops** BMO: CAPABILITY

4.3 The Sub-Ontology FEI Agile New Concept Development

The next Sub-Ontology is illustrated in Figure 4-8 Sub-ontology FEI Agile New Concept Development (NCD). The Agile Project Management Approach is flexible and appropriate for the predevelopment stages of the innovation, consequently, it is an adequate fit to cope with the existing dynamic in the FEI (Gonzalez, 2014). Agile methods have an emphasis on being flexible to changes in requirements, as well as working in collaboration with customers and other stakeholders (Parsons, 2011).

The FEI AGILE NCD is **guided** by the FEI EO: STRATEGIC PURPOSE and it is **framed** by the PORTFOLIO PLANNING & MANAGEMENT. Moreover, it **aggregates iterations**, therefore it incorporates the FEI ITERATION (see Box 4-5) and it **produces** NEW CONCEPT. A formal definition of iteration is that it refers to the process of doing something, again and again, generally to improve it (Cambridge Dictionary, 2017). The FEI ITERATION corresponds to a (re)arrangement of activities and resources supportive to the development of the NEW CONCEPT. It will offer feedback to the PORTFOLIO PLANNING & MANAGEMENT and eventually will adjust the FEI EO: STRATEGIC PURPOSE.

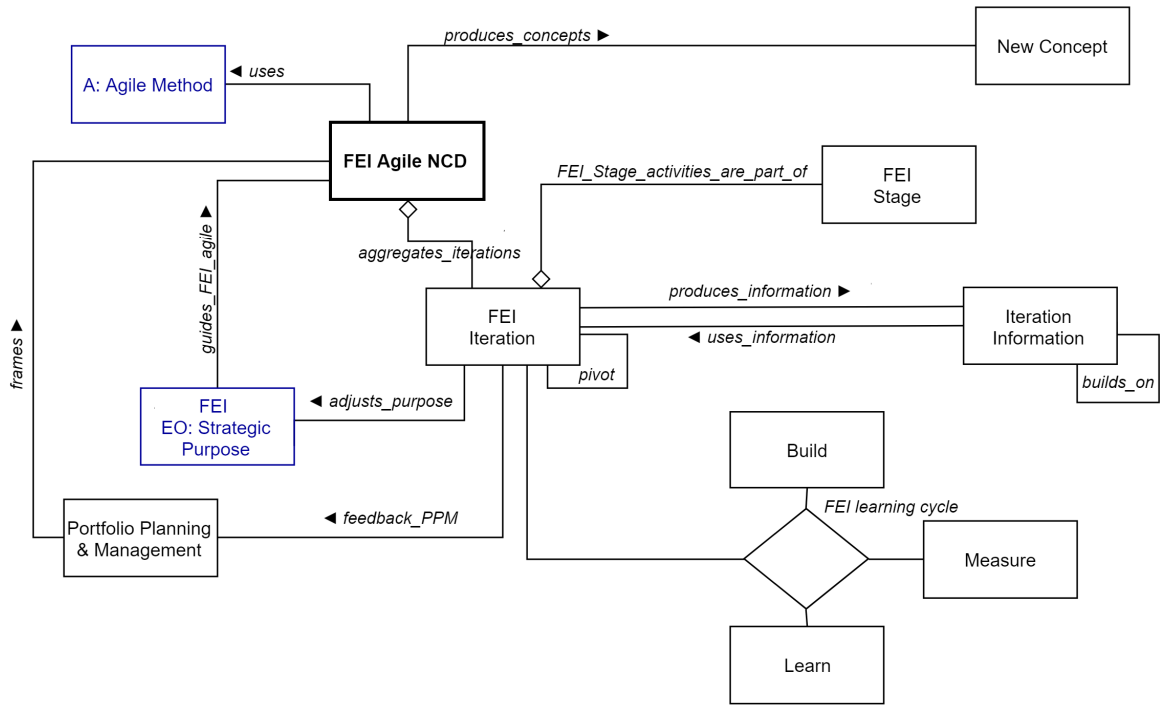

Figure 4-8 Sub-ontology FEI Agile New Concept Development

Box 4-5 presents an additional perspective, in natural language, of the Sub-ontology FEI Agile New Concept Development.

Box 4-5 – Description in natural language of the Sub-ontology FEI Agile New Concept Development

FEI AGILE NCD **uses** AGILE METHOD
FEI AGILE NCD **aggregates_iterations** FEI ITERATION
FEI AGILE NCD **produces_concepts** NEW CONCEPT
FEI STAGE **FEI_Stage_activities_are_part_of** FEI ITERATION
FEI ITERATION **pivot** FEI ITERATION
FEI ITERATION **adjusts_purpose** FEI EO: STRATEGIC PURPOSE
FEI EO: STRATEGIC PURPOSE **guides_FEI_agile** FEI AGILE NCD
FEI ITERATION **feedback_PPM** PORTFOLIO PLANNING & MANAGEMENT
PORTFOLIO PLANNING & MANAGEMENT **frames** FEI AGILE NCD
FEI ITERATION **produces_information** INTERATION INFORMATION
INTERATION INFORMATION **uses_information** FEI ITERATION
INTERATION INFORMATION **builds_on** INTERATION INFORMATION
Quaternary association FEI LEARN CYCLE *relating four classifiers* BUILD, MEASURE, LEARN, FEI ITERATION

The FEI AGILE NCD sub-ontology focuses on the integrative and iterative concept development while the FEI STAGE addresses the activities. The list below further explores the features of the FEI AGILE NCD.

a) This sub-ontology produces the NEW CONCEPT that will enter into the NPD for further commercialization, illustrated in Figure 4-9. The NEW CONCEPT is the result of the FEI. It also acts as the input for the New Product Development and for the Commercialisation Phase (Koen et al., 2002; The authors, 2017). The FEI AGILE NCD may produce several NEW CONCEPTS (prototypes) until it reaches a NEW CONCEPT.

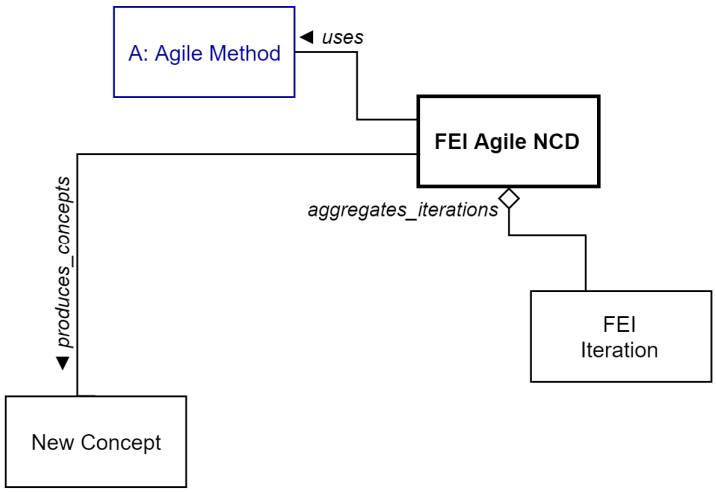

Figure 4-9 Sub-ontology FEI Agile NCD [New Concept]

b) The FEI AGILE NCD may adjust the FEI EO: STRATEGIC PURPOSE due to the content of the FEI ITERATIONS (Figure 4-10). The FEI ITERATION works in successive BUILD/MEASURE/LEARN cycles enabling its progress towards a desired end. The BUILD concept represents a construction of something (i. e. the so-called Minimum Viable Product). Therefore, the MEASURE concept deals with measuring customer and/or client feedback, as well as Lead User feedback. It is useful to assess and to help define the NEW CONCEPT. Lastly, LEARN activities, not only BUILD and MEASURE, elucidate the cause and effect relationships.

c) The FEI ITERATION offers **feedback** to the PORTFOLIO PLANNING & MANAGEMENT. While the FEI AGILE NCD learns with the results of FEI ITERATIONS, this feature is demonstrated in Figure 4-10.

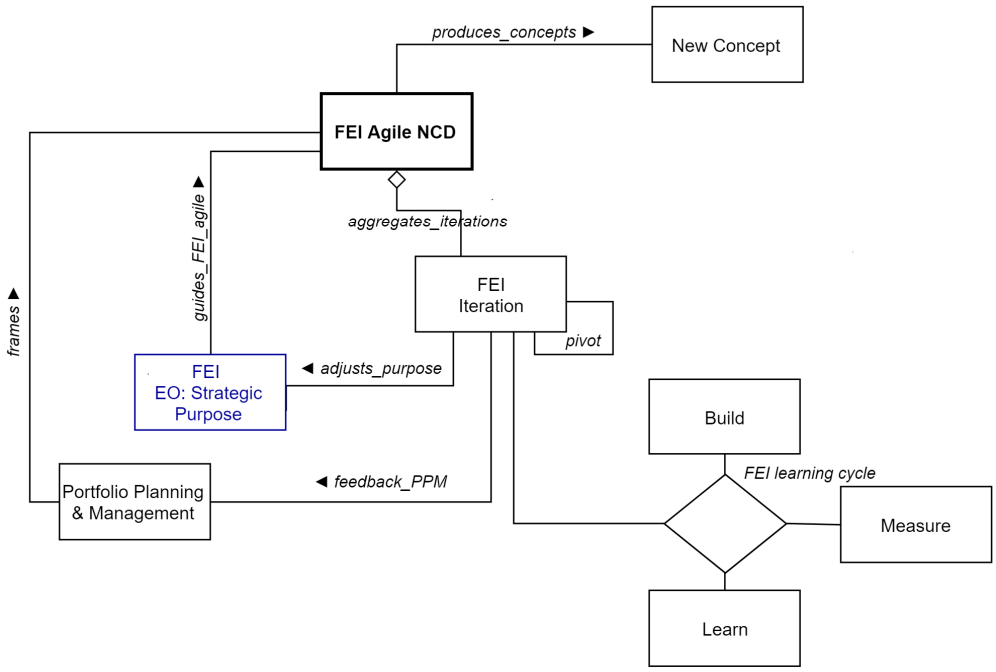

Figure 4-10 Sub-ontology FEI Agile NCD [FEI Iteration Outputs]

d) This sub-ontology depicts the dynamic flow of pivoting; thus, it is developed considering Agile principles, namely BUILD, MEASURE and LEARN (Ries, 2011). Figure 4-11 illustrates this feature associated to each iteration.

e) The learning process is further reflected by the information gathering, which supports the knowledge building through succeeding iterations. This process is broaden with the relations: **produces information** and **uses information.** Figure 4-11 shows this process.

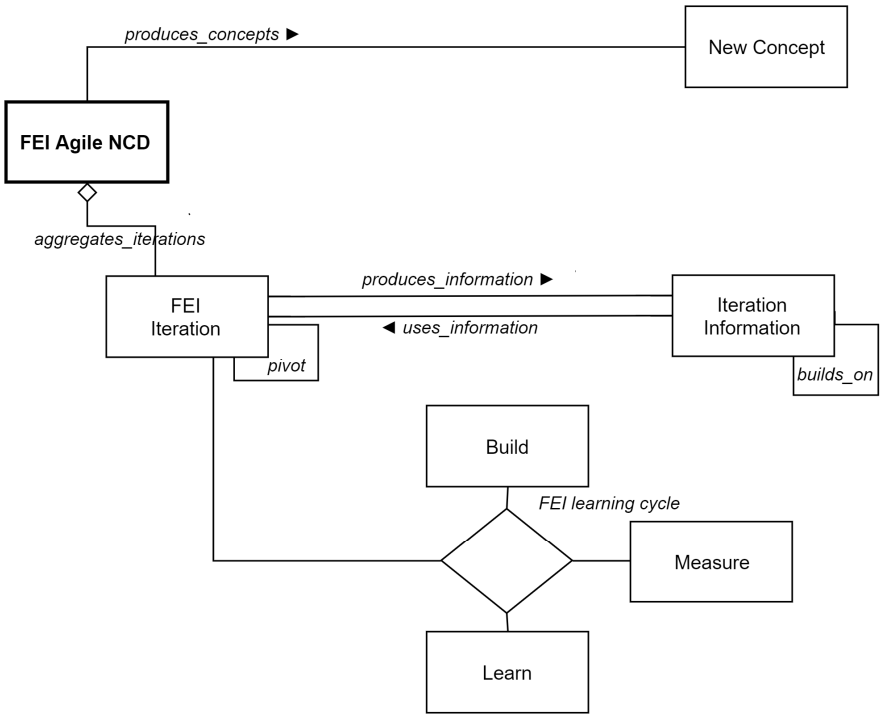

Figure 4-11 Sub-ontology FEI Agile NCD [Dynamic Flow and Learning Cycle]

4.4 The Sub-Ontology FEI Stage

The FEI Stage represents sets of activities envisioned for the beginning of the innovation process. They are not linear despite the static view, in fact, they carry a dynamic and iterative flow among them enabled by the FEI ITERATION (BUILD/MEASURE/LEARN loop). The concept stage was chosen to depict the organisation of activities, as it represents a period of development, with expected outcomes and deliverables. A FEI STAGEs is the PRELIMINARY OPPORTUNITY IDENTIFICATION (POI); the PRODUCT CONCEPT DEFINITION (PCD); the FEASIBILITY AND PROJECT PLANNING (FPP), and BUSINESS MODEL DEVELOPMENT (BMD). Figure 4-12 illustrates the FEI Stage sub-ontology.

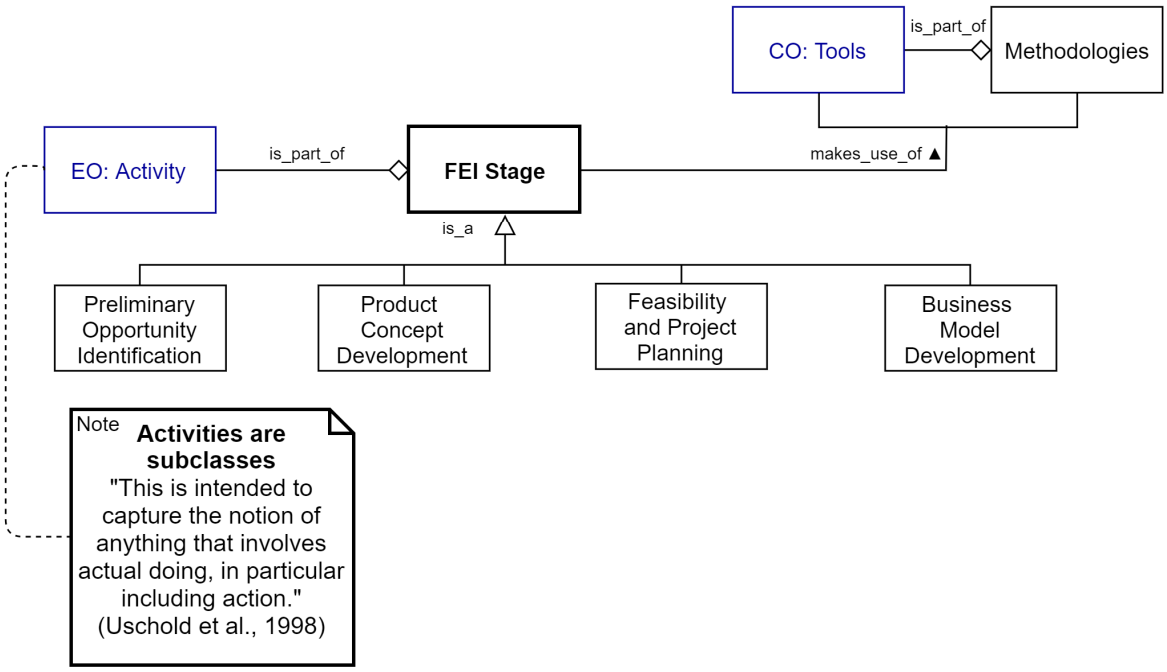

Figure 4-12 Sub-ontology FEI Stage

The representation of FEI activities in a set of stages aims to facilitate the decision-making process as well as to provide a management perspective of all the responsibilities entailed by each stage. Box 4-6 presents a further perspective of the Sub-ontology FEI Stage.

Box 4-6 – Description in natural language of Sub-ontology FEI Stage

EO: ACTIVITY **is_part_of** FEI STAGE
FEI STAGE **makes_use_of** CO: TOOLS
FEI STAGE **makes_use_of** METHODOLOGIES
CO: TOOLS **is_part_of** METHODOLOGIES
PRELIMINARY OPPORTUNITY IDENTIFICATION **is_a** FEI STAGE
PRODUCT CONCEPT DEVELOPMENT **is_a** FEI STAGE
FEASIBILITY AND PROJECT PLANNING **is_a** FEI STAGE
BUSINESS MODEL DEVELOPMENT **is_a** FEI STAGE

This sub-ontology took into consideration much of the work from Khurana and Rosenthal (1997, 1998) concerning concepts related to the FEI phases. The stages PRELIMINARY OPPORTUNITY IDENTIFICATION and PRODUCT CONCEPT DEVELOPMENT are

continuously active and provide feedback for FEASIBILITY AND PROJECT PLANNING and BUSINESS MODEL DEVELOPMENT.

The BUSINESS MODEL DEVELOPMENT was also considered as an FEI Stage because there is theoretical support for this, for instance:

- For Markham et al. (2010) the FEI comprises works, such as: as technical feasibility validations, early market research, financial viability analysis, business model development, and business plan preparation.
- Eckhardt (2013) argues that opportunities can be exploited by designing business.
- As advocated by Martinsuo & Poskela (2011), the FEI may open up strategic opportunities that drive business renewal.

Therefore, the main responsibilities of each of these stages are the following:

- PRELIMINARY OPPORTUNITY IDENTIFICATION (POI). It represents the identification of opportunities that an organisation or an entrepreneur might want to pursue. It includes ideation activities and also defines the market and/or technology arena that the organisation/start-up may want to take part (Koen et al., 2002; The author, 2017).
- PRODUCT CONCEPT DEVELOPMENT (PCD). The product concept and definition are shaped. The concept definition may still be subject to fine-tuning. This stage produces evaluations about the target market, competitive landscape, and plans concerning the expected time and resources needed to bring the product to the market. Thus, it is responsible for identifying customer and user needs/wants/fears, competitive scenario and technologies (Khurana and Rosenthal, 1997; The author, 2017).
- FEASIBILITY AND PROJECT PLANNING **-** Feasibility analysis and project planning are important activities to help the business development. They play a vital role in determining the potential for success of a new concept or business venture (Hofstrand and Holz-Clause, 2009).

- BUSINESS MODEL DEVELOPMENT - A Business Model is conceptual model of a business by which a company creates and delivers value to its customers, and the payment for the value convertes in profits (Teece, 2010). Therefore, the activities of this stage help to shape the BM.

Table 4-2 illustrates examples of activities found in each of the FEI STAGEs.

Table 4-2 Example of FEI activities according to each FEI Stage

Stage	**Example of activities**
POI	Ideation; Market Analysis; Technology Analysis
PCD	Identify Customer Needs; Identify Customer Wants; Identify Customer Fears; Identify Market Segments; Identify Competitive Scenario; Technology Evaluation; Problem-Solution Fit
FPP	Proposed Minimum Viable Product; Specify Resources Needed; Project Description; Market Feasibility; Technical Feasibility; Financial / Economic Feasibility; Organizational / Managerial Feasibility; Identify Key Risks and Challenges
BMD	Product Market Fit; Business Model Prototype; Sales & Marketing Roadmap; Scale Execution; Scale Organisation; Scale Operation

These activities may count with the aid of TOOLS and METHODOLOGIES. Figure 4-13 illustrates the relationship between these concepts. In other words, an FEI STAGE **makes use of** TOOLS and **makes use of** METHODOLOGIES, considering that METHODOLOGIES are an aggregation of CO: TOOLS. A tool is something that is designed, built or installed, in order to serve in a specific action by providing convenience, efficiency or effectiveness (Leppänen, 2005). Hence, other existing or new tools and supporting methodologies may be used in any FEI STAGE as of assistance with FEI activities.

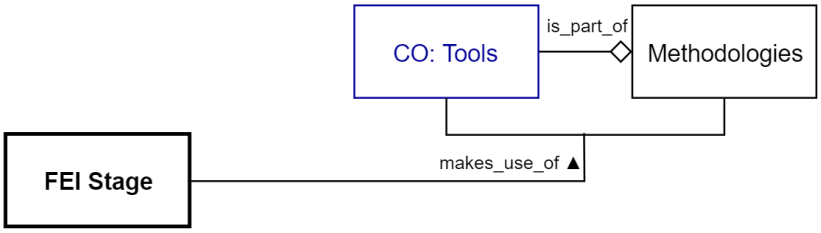

Figure 4-13 Sub-ontology FEI Stage [Tools and Methodologies]

Nonetheless, it is necessary to put special emphasis in the dynamic nature of the FEI, in this case, FEI activities may or may not be accomplished in a sequential flow. Projects must pass through logical phases of development, even if they must repeat an activity or regress through iterative loops – this was explored through the FEI ITERATION concept. Therefore, the FEI^{2}O encompasses the argument of Markham, Ward, Aiman-Smith, & Kingon (2010) that even though activities may be iterative, the project must develop toward a discernible state of development.

4.5 The Sub-Ontology FEI Actors

Another component of the FEI Integrative Ontology corresponds to the **FEI Actors Sub-Ontology**, shown in Figure 4-14. This sub-ontology focuses on concepts as actors and their roles in the early stage of innovation.

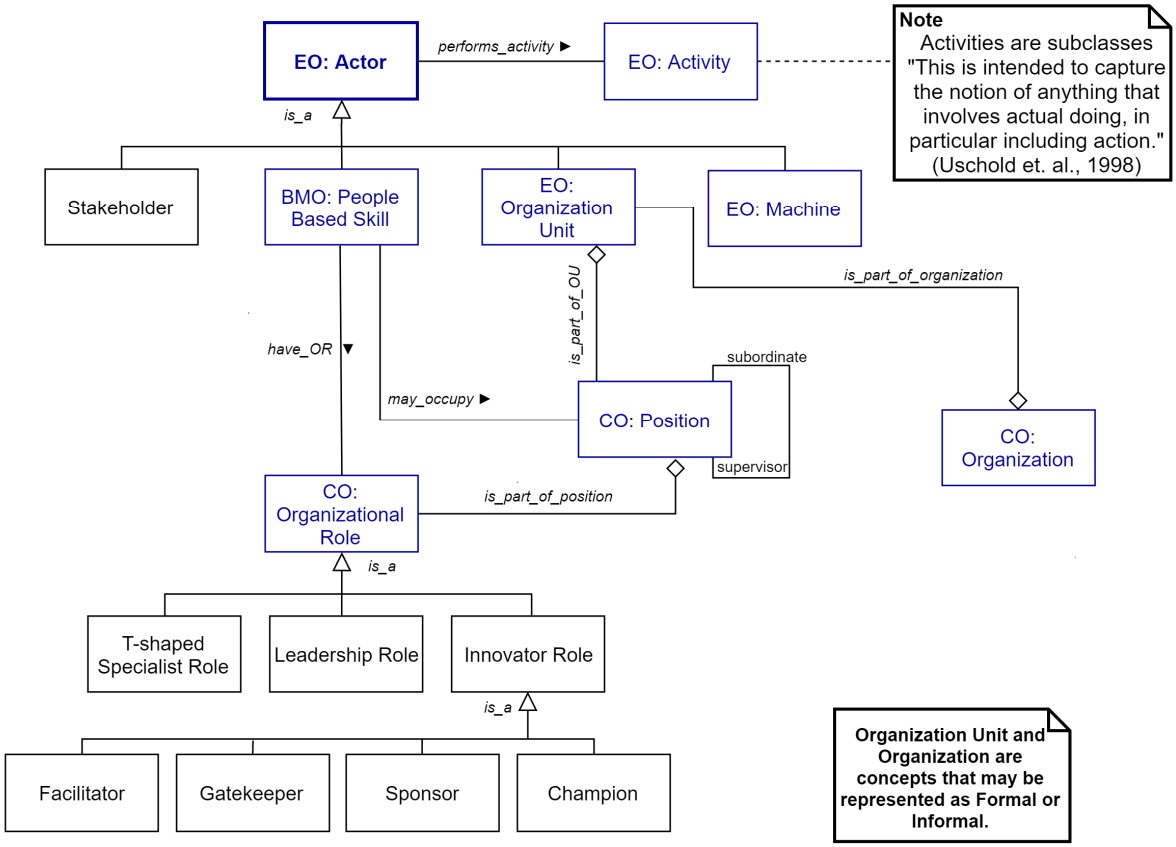

Figure 4-14 Sub-ontology FEI Actors

EO: ACTOR refers to an entity that plays an actor role in a relationship (Uschold et al., 1998), in this case, actors that perform an activity in the FEI. The responsibilities of actors are to perform, to own, to communicate, to borrow, to send, and to receive objects in the FEI. Actors are not only humans but also machines as well as the various combinations of humans and machines (Storbacka, Brodie, Bohmann, Maglio, & Nenonen, 2016).

The concepts ORGANISATION UNIT and ORGANISATION may be FORMAL or INFORMAL to represent the reality of an established company and a start-up. The roles and actors might be the same for both realities. However, the roles and actors in the FEI are expected to vary in degree and number. Box 4-7 presents the Sub-ontology FEI Actors.

Box 4-7 – Description in natural language of Sub-ontology FEI Actors

EO: ACTOR **performs_activity** EO: ACTIVITY
STAKEHOLDER **is_a** EO: ACTOR
BMO: PEOPLE BASED SKILL **is_a** EO: ACTOR
EO: ORGANIZATION UNIT **is_a** EO: ACTOR
EO: MACHINE **is_a** EO: ACTOR
BMO: PEOPLE BASED SKILL **have_or** CO: ORGANIZATIONAL ROLE
BMO: PEOPLE BASED SKILL **may occupy** CO: POSITION
CO: ORGANIZATIONAL ROLE **is_part_of_position** CO: POSITION
CO: POSITION **is_part_of_OU** CO: ORGANIZATIONAL UNIT
CO: POSITION **can_be** SUBORDINATE
CO: POSITION **can_be** SUPERVISOR
CO: ORGANIZATION UNIT **is_part_of_organization** CO: ORGANIZATION
T-SHAPED SPECIALIST ROLE **is_a** CO: ORGANIZATIONAL ROLE
LEADERSHIP ROLE **is_a** CO: ORGANIZATIONAL ROLE
INNOVATOR ROLE **is_a** CO: ORGANIZATIONAL ROLE
FACILITATOR **is_a** CO: INNOVATOR ROLE
GATEKEEPER **is_a** CO: INNOVATOR ROLE
SPONSOR **is_a** CO: INNOVATOR ROLE
CHAMPION **is_a** CO: INNOVATOR ROLE

According to the Enterprise Ontology, EO: ACTOR is an entity that plays an actor role in a relationship (Uschold et al., 1998), in this case, actors that perform an activity in the FEI. As illustrated in Figure 4-15, the Sub-Ontology FEI Actor considers the following concepts as

ACTORS: STAKEHOLDER; BMO: PEOPLE BASED SKILL; EO: ORGANIZATION UNIT; and, EO: MACHINE.

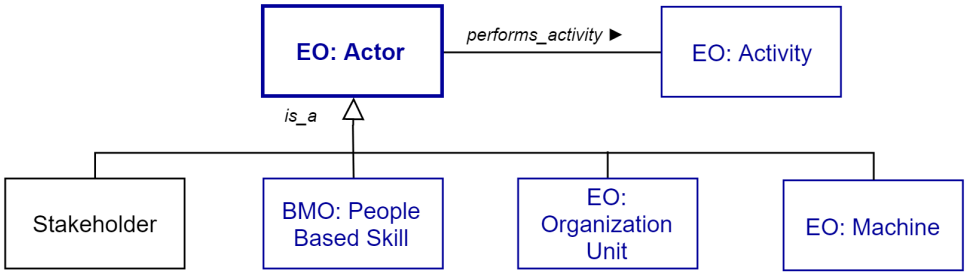

Figure 4-15 Sub-ontology FEI Actor focus on Actor

As organisational roles are significant for FEI activities, they are illustrated in Figure 4-16.

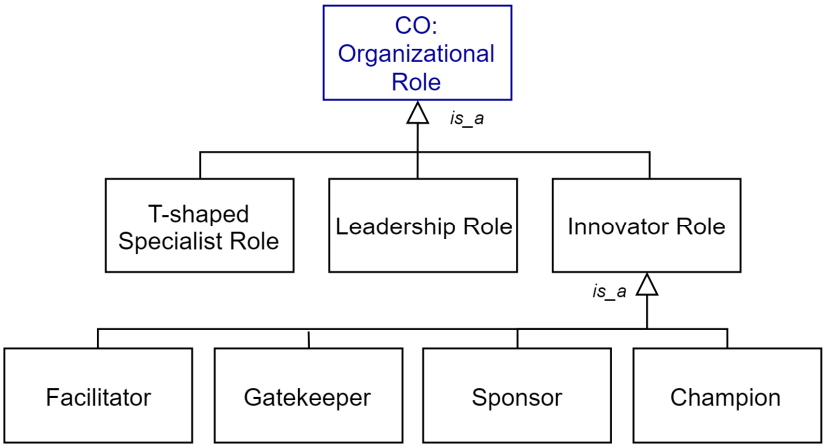

Figure 4-16 Sub-ontology FEI Actor focus on CO: Organizational Role

A CO: ORGANIZATIONAL ROLE is a collection of responsibilities, stipulated in an operational or structural manner (Leppänen, 2005). For this sub-ontology, three roles and their specializations are considered:

- T-SHAPED SPECIALIST ROLE – This role represents any professional involved in the innovation process. It consists of the notion that a T-shaped specialist is someone who shares knowledge freely across the organisation (denoted by the horizontal part of the "T"). At the same time, this professional has a strong specialised knowledge

committed to a specific business unit performance (the vertical part) (Hansen and Oetinger, 2001).

- LEADERSHIP ROLE – There are several leadership behaviours identified as influencers of people's willingness to engage in innovative efforts (Rekonen & Björklund, 2016). It is not the aim of this work to detail all of the possible leadership behaviours; it is only emphasises the need of a leadership role.
- INNOVATOR ROLE – It represents informal roles frequently found in the innovation literature. Their activities establish interactions between each other to cross the so-called "valley of death" (Markham et al., 2010).
    - FACILITATOR helps to bring about an outcome by providing indirect or unobtrusive assistance, guidance, or supervision (Merriam-Webster, 2017).
    - CHAMPION adopts and advocates a project (Markham et al., 2010).
    - SPONSOR provides project sanctioning and resources (Markham et al., 2010).
    - GATEKEEPER establishes criteria and makes decisions concerning the future of the project (Markham et al., 2010).

Figure 4-17 illustrates an excerpt of the sub-ontology focusing on STAKEHOLDER. Stakeholders can be understood as "any group or individual who can affect or is affected by the achievement of the organization's objectives" (Freeman, 1984, p. 46), some of them are internal while others are external. Furthermore, in this sub-ontology, they represent a specialisation of the Concept USER. The concept definitions of each STAKEHOLDER can be found in Table 4-3.

Table 4-3 Stakeholder – Concept Definitions

Concept	**Definition**
EO: Owner	Ownership is the union of legal ownership and non-legal ownership (Uschold et al. 1998).
EO: Shareholder	It stands for a legal entity owning one or more shares in a corporation (Uschold et al. 1998). It also may represent an investor interested in taking part of the business (The authors, 2017).
BMO: Value Network	The value network is composed of suppliers, partners and coalitions (Osterwalder et al., 2004).
BMO: Partner	Stakeholders that supply complements to a final product or solution (Osterwalder et al., 2004).

Concept	Definition
BMO: Coalition	Coalitions are alliances with like-minded competitors (Osterwalder et al., 2004).
BMO: Supplier	The supplier is an entity that provides something needed such as a product or service (Osterwalder et al., 2004).
Media	The media plays an expressive role concerning the business communication (Freeman, 1984).
Environmentalists	Environmental protection agencies and others institutionalised environmental initiatives are an example of environmentalists' stakeholders (Freeman, 1984).
Special Interest Groups	Special Interest Group may also be recognised as Social Interest Groups or Single-Issue Politics. The idea here is that a group or an individual can use the political process to further a position on a particular issue (Freeman, 1984).
Entrepreneur	It is the person responsible for driving the creation of a new venture (Wimmer, 2016).
Employees	A person who works part-time or full-time under a contract of employment and has recognised rights and duties (Business Dictionary, 2017).
Customer	A party (eventually called as a client) that receives or consumes products (goods or services) and has the ability to choose between different products and suppliers (Business Dictionary, 2017; The authors, 2017).
User	A user is an entity that has the authority to use an application, equipment, facility, process, or system. Additionally, it may be considered as one who consumes or employs a good or service to obtain a benefit or to solve a problem, and who may or may not be the actual purchaser of the item (Business Dictionary, 2017).
Lead User	A Lead User represents someone that is at the leading edge of an important market trend. A Lead User has a high need for solutions to the novel needs he/she has encountered at that leading edge (von Hippel et al., 2009).
Government	There are several possible interactions among businesses and government actors that impact the company (Freeman, 1984). Government refers to the group of people who officially control a country (Cambridge Dictionary, 2017).
Community	It is the local community organised (Freeman, 1984).

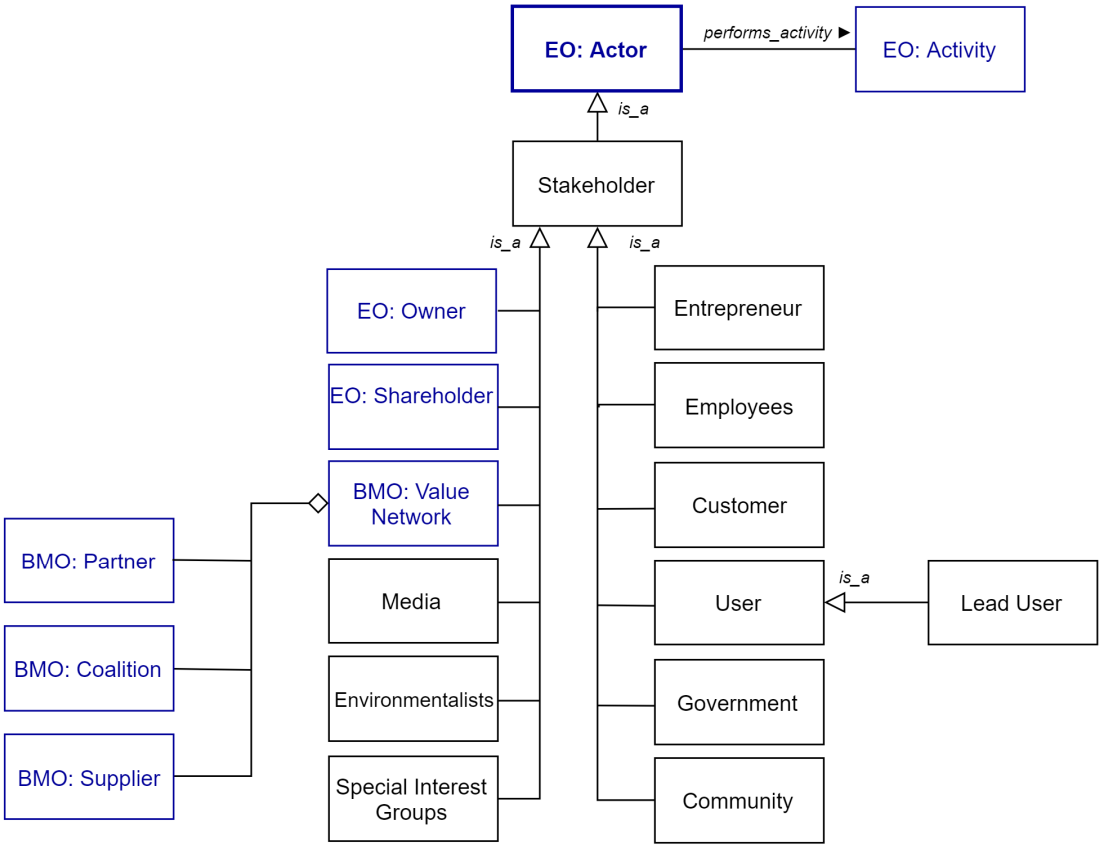

Figure 4-17 Sub-ontology FEI Actor focus on Stakeholder

Box 4-8 presents a further perspective of the Sub-ontology FEI Actors focused on Stakeholder specialisations.

Box 4-8 – Description in natural language of Sub-ontology FEI Actors [Stakeholder]

EO: OWNER **is_a** STAKEHOLDER
SHAREHOLDER **is_a** STAKEHOLDER
BMO: VALUE NETWORK **is_a** STAKEHOLDER
MEDIA **is_a** STAKEHOLDER
ENVIRONMENTALIST **is_a** STAKEHOLDER
SPECIAL INTEREST GROUPS **is_a** STAKEHOLDER
ENTREPRENEUR **is_a** STAKEHOLDER
EMPLOYEES **is_a** STAKEHOLDER
CUSTOMER **is_a** STAKEHOLDER
USER **is_a** STAKEHOLDER
GOVERNMENT **is_a** STAKEHOLDER
COMMUNITY **is_a** STAKEHOLDER
LEAD USER **is_a** USER

BMO: PARTNER **is_part_of** BMO: VALUE NETWORK
BMO: COALITION **is_part_of** BMO: VALUE NETWORK
BMO: SUPPLIER **is_part_of** BMO: VALUE NETWORK

A special case of the Concept Stakeholder is the BMO: VALUE NETWORK composed by BMO: SUPPLIERS, BMO: PARTNERS and BMO: COALITIONS (Osterwalder et al., 2004):

- Suppliers as entities that provide something needed such as a product or service;
- Partners as those who supply complements to a final product or solution; and,
- Coalitions are alliances with like-minded competitors.

4.6 The High-Level Sub-Ontology

The relations explored in detail in the sub-ontologies FEI Purpose; FEI Stage; FEI Portfolio and Planning; FEI Agile NCD; and, FEI Actors are now presented in a High-Level demonstration in Figure 4-18.

Figure 4-18 shows the High-Level Inter-Domain Key Relationships dynamic proceedings and principal elements, including their relations, concerning the FEI activities. In this representation, the FEI EO: STRATEGIC PURPOSE **contributes to** the PORTFOLIO PLANNING & MANAGEMENT-PP&M. In its turn, the PP&M frames the FEI AGILE NEW CONCEPT DEVELOPMENT-NCD, while the FEI EO: ACTORS **are engaged** in the FEI Agile NCD to produce the NEW CONCEPT. The FEI AGILE NCD entails a combination of iterations. These iterations consist of a configuration of activities considered in the FEI Stage. This process continues as long as necessary to achieve a NEW CONCEPT.

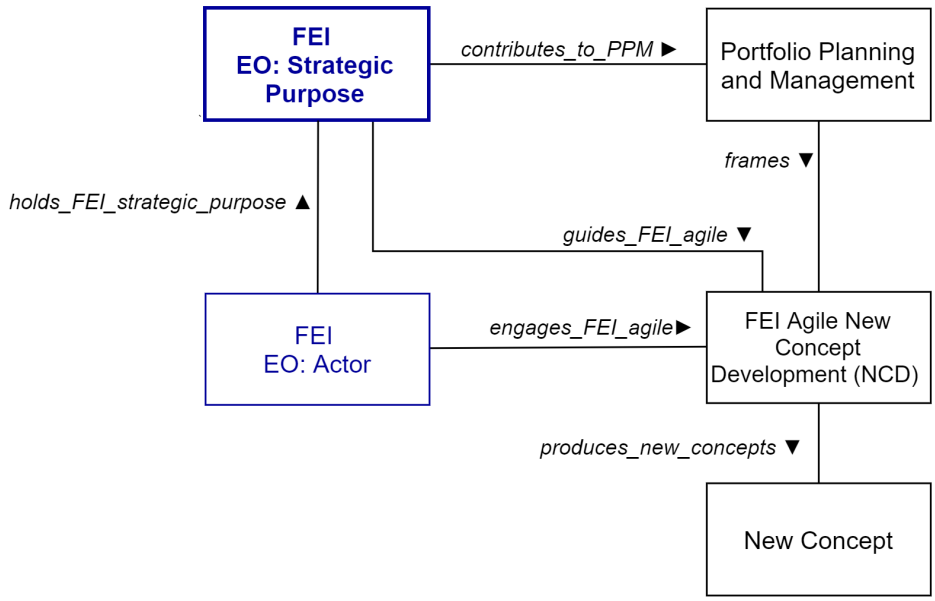

Figure 4-18 High-Level Inter-Domain Key Relationships

The possibility to have preliminary versions of the NEW CONCEPT (prototypes) allows the FEI EO: ACTORS to minimise the risks of innovation. For instance, the FEI AGILE NCD will iterate; therefore, it will BUILD / MEASURE / LEARN in order to have a NEW CONCEPT.

4.7 Conclusion

The FEI^{2}O represents a consistent addition to the FEI domain, as this model holds the potential to share, between people, formal and collective understanding of the FEI structure, concepts and its relations. It benefited of the reuse of concepts from other ontologies, of FEI literature and also comprised the contribution of domain experts. This representation is more than a taxonomy, as it addresses the complexity of a shared and transferable knowledge. Moreover, it comprises the ontology advantage of semantic expressiveness and modelling power, by capturing complex FEI concepts considering their semantics and representing the relations among them. The modelling of the FEI^{2}O by means of an ontology facilitates the creation of an integrated view for the users, by shaping a comprehensive representation of the FEI domain with its concepts and relations. These concepts and relations are modelled in a set of sub-ontologies, organised according to FEI drivers: Opportunity and Purpose, Portfolio Planning

& Management and Organisational Factors, Agile Development, FEI activities (Stages) and Actors (and roles).

There is a broad audience that can benefit from the ontology, namely entrepreneurs, practitioners, scholars, R&D groups, managers, technology transfer office, venture capital firms, business angels, professors and educational institutions responsible for teaching innovation and entrepreneurship.

The FEI^{2}O provides a comprehensive and integrative view of FEI responsibilities and activities in order to achieve the development of a new concept. This model supports the decision of which opportunities, ideas and concepts are worth to developed by addressing organisational, technological and market issues.

The FEI^{2}O as a formal model may receive further maintenance. Therefore, the set of FEI activities may benefit of future expansions, encompassing the development of this knowledge domain. In sum, the list of suggested FEI activities is not comprehensive and may be fine-tuned over time. Moreover, the FEI^{2}O frames the use of tools and methodologies that may be used to develop FEI Activities. The list of these tools and methodologies is extensive and it was not the aim of this work to explore them.

The next chapter presents the manner by which the exploratory phase of the ontology unfolded, as well as the results obtained along that process and in the final validation phase.

Chapter 5 Ontology Evaluation

This chapter presents the evaluation process responsible for gathering technical judgment concerning the Front End of Innovation Integrative Ontology and served as a proof for the usefulness of the developed artefact (Staab et al., 2001). The evaluation process consisted of a two-phase approach: an exploratory and a validation. The Exploratory allowed the ontology expansion and revision of terms and relations as well as its refinement. The evaluation process advanced for the next phase only after reaching data saturation. The Validation addressed the confirmation of the work as well as the answers to the competence questions. Figure 5-1 summarizes the evaluation process in the context of the ontology development undertaken in this thesis.

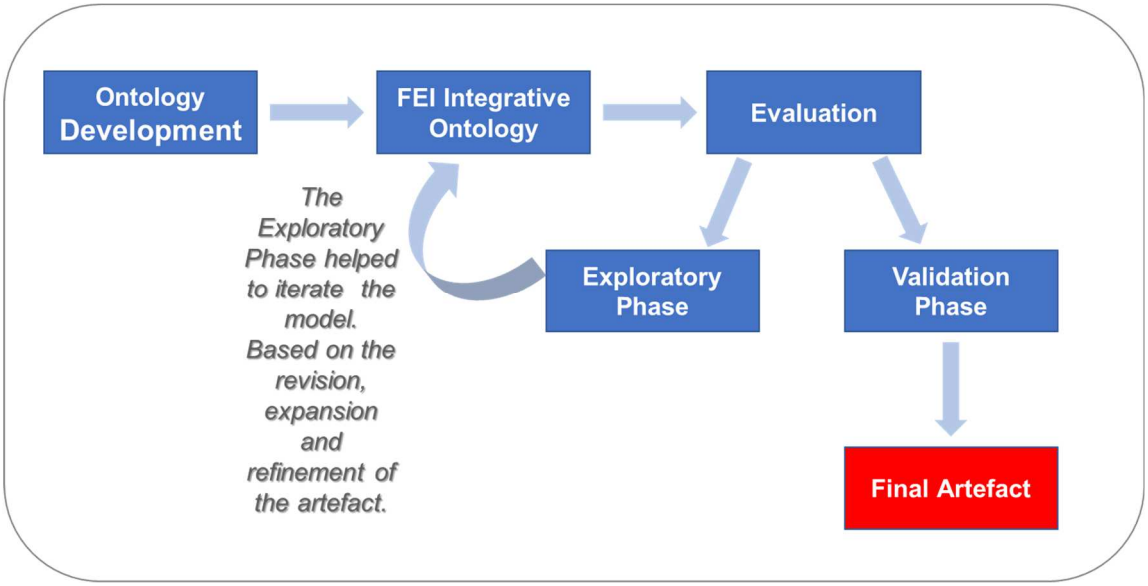

Figure 5-1 Ontology Evaluation Procedure

5.1 Exploratory Phase

Design science, as one component of the Information System research cycle, creates and evaluates IT artefacts intended to solve identified organizational problems (Hevner et al., 2004). Moreover, design-science research produces four design artefacts (Constructs, Models, Method, Instantiations) by the application of two processes: build and evaluate (March & Smith, 1995). The Build process was addressed in Chapter 4 whereas Chapter 5 addresses the Evaluate process.

The first phase of evaluation was the so-called Exploratory Phase, which was responsible for:

- Exploratory concept elicitation with domain experts, in order to evaluate both the terms and the relations implemented by the FEI Integrative Ontology on a sub-ontology basis.
- Revision, expansion and refinement of the artefact based on feedback.

This exploratory evaluation was developed from June/2016 until May/2017, it consisted of interviews with domain experts. The first stage comprises feedback from domain experts. The constructive criticism by means of revision, expansion and refinement of the artefact allowed the improvement of the model.

Table 5-1 Exploratory Evaluation Interviews

ID	Date	Mode	Expertise / Position
1	Jun, 17th	Physical Interview	Researcher and Professor of Computer Science and Quantitative Methods
1	Jun, 24th	Video Conference Call	Researcher and Professor of Computer Science and Quantitative Methods
2	Jun, 27th	Physical Interview	Head of a Centre for Innovation, Technology and Entrepreneurship and Entrepreneurship Professor
1	Jul, 05th	Video Conference Call	Researcher and Professor of Computer Science and Quantitative Methods
2	Jul, 11th	Physical Interview	Head of a Centre for Innovation, Technology and Entrepreneurship and Entrepreneurship Professor
3	Jul, 18th	Physical Interview	Head of a Technology Transfer Office
4	Jul, 19th	Physical Interview	Technology Director of a Venture Capital

ID	Date	Mode	Expertise / Position
1	Sep, 30th	Video Conference Call	Researcher and Professor of Computer Science and Quantitative Methods
5	Oct, 21st	Video Conference Call	Start-up Founder and CEO, Expert in Artificial Intelligence (Machine Learning, Natural Language Processing, Semantic Search)
6	Jan, 26th	Physical Interview	Technological Entrepreneur
7	Jan, 26th	Video Conference Call	Production Director - Industry of Telecommunications
8	Jan, 30th	Video Conference Call	Technological Entrepreneur
9	Feb, 03rd	Physical Interview	Technological Entrepreneur
10	Feb, 07th	Physical Interview	Entrepreneur and Member of the Advisory Board of a Master in Innovation and Technological Entrepreneurship
11	Mar, 15th	Physical Interview	Head of Innovation and Future Tech of a Large Portuguese Retail Group
12	May, 11th	Video Conference Call	Entrepreneur, Business Developer and Professor
13	May, 11th	Video Conference Call	Professor and Managing Editor of Studies of Organisational Management & Sustainability
14	May, 15th	Video Conference Call	Professor of Technology-Based Entrepreneurship

A total of 18 interviews with 14 participants enriched and refined the proposed artefact. The next paragraphs present the main remarks concerning the participant's contributions, analysis, critiques and highlights.

Participant 1 is a researcher who works in Information Technology and Enterprise Integration for the Fuzzy Front End of Innovation. Due to his expertise, he offered vital contributions regarding the design of the ontology and its content. Therefore, he was asked to participate in the exploratory phase more than once.

Similarly, Participant 2 provided an essential contribution as this participant is not only Head of an Innovation, Technology and Entrepreneurship Centre but also an Entrepreneurship Professor. She offered critics and comments regarding the practical approach of the work.

Participant 3 said the model was comprehensive and that it was an interesting tool to help managers and staff to know about the FEI developments. She said that a manager has a different point of view than a facilitator or an investor. Therefore, a practical approach with multifaceted view, considering different actors and roles in the FEI would be highly appreciated. This request may be fulfilled in furthers developments of the FEI^{2}O Canvas, as this is a by-product its development is not comprised in the scope of this thesis.

Participant 4 questioned about the suitability of the model for Start-ups from different market fields, as the requirements from pharmaceutical and nanotechnologies firms are different. Moreover, he argues that the model is a promising tool to help entrepreneurs to deal with the FEI.

Participant 5 provided important assessments and contributions due to his background as a Start-up/CEO Founder and as an Expert/Professor in Artificial Intelligence in topics such as Machine Learning, Natural Language Processing and Semantic Search. Therefore, Participant 5 has both experience as an entrepreneur and technical background concerning the consistency of the ontology. This vantage point allowed him to provide a thorough analysis of the work. He called attention to the need to reconsider the class: CO: Requirements, as in his point of view CO: Requirements Child's Class needed a more homogeneous approach, as it is a concept of the FEI Purpose. The sub-ontology was subject to refinement, and this class was re-alocated offering a more suitable attention to the concept. In his opinion, the model was exhaustive, complete.

Participant 6 is a technology-based entrepreneur with experience in the software and electronic devices industries. According to him, the concepts and relations of the ontology were suitable to the FEI. However, he stressed the importance of the actor's engagement concept, as he experienced it to be of vital importance in his entrepreneurship journey. Moreover, the literature also supports his argument, therefore, this concept was included as a property of the Actor class in the High-Level Ontology.

Insights from a large industry came from the contribution of Participant 7. He emphasised that in the telecommunication industry ideas usually come from Marketing, R&D, Clients and/or User needs. This highlight was important to expand the sub-ontology FEI Actor and to include

the User with differentiation from Client. In addition, Participant 8 validates this suggestion, emphasising that user and client are different actors in the FEI.

For Participant 7, the FEI Integrative Ontology might be helpful to accelerate the innovation process, as the entrepreneur will have a methodological orientation capable of minimising the trial and error approach. Another benefit, noted by this participant, is that the iteration process may play a pilot project role concerning the initial efforts to commercialise a product.

Participant 8, an entrepreneur from a Brazilian Start-up, remarks on the FEI Integrative Ontology: "In practice, we do not see it as structured as it is (…), but it makes much sense". Through the exploratory phase, the FEI^{2}O iterates as a response to the concept elicitation and revision of terms and relations of the artefact. The version presented to Participant 8 comprised a view of the FEI Stage with a set of activities for each of the four stages. Therefore, the entrepreneur asked if the model could present a feature capable to identify the hierarchical need of each activity/stage. This request is in line with the view of a Head of Innovation and Future Tech department in a large Portuguese retail chain. As well as with the view from Participant 14, who is a professor of technology-based entrepreneurship.

The iterative nature of the FEI offers space for a dynamic configuration and sequence of FEI activities. Exhaustive analysis was given to the modelling of FEI activities using UML representation. The FEI activities complexity would convey a dense visualisation, which presents difficulties for the reader. The best compromise consists of presenting the four FEI STAGEs in the FEI^{2}O while their activities´ dynamics is depicted in the FEI ITERATION. The subset of FEI supporting activities is complementary to the ontology and comprises activities chosen according to the needs of FEI actors. This solution allows a further proposition of guidelines concerning hierarchical needs of FEI Activities, as well as a management tool for the FEI in the form of a checklist.

Moreover, participant 8 emphasised the utility of the model, as it allows the entrepreneur to have a vision about their product/business, capable of fostering an adequate strategy to aggregate value to the delivered product/service. His overall appreciation was that the model was complete, hence no concept or relation was missing in the representation.

Participant 9 is one of the founders of a Portuguese Start-up that develops technology to produce energy in trucks. Furthermore, he could easily read the FEI^{2}O proposition, as this participant was familiar with the UML notation. He raised questions concerning the sub-ontology FEI Purpose, more specifically to the complexity of this representation. These remarks were taken into account and after considerable analysis a simplified version of this sub-ontology was developed.

Participant 10 provided a management perspective for the concept organisation, offering as sub-classifications, for the sub-ontology FEI Actors, the specialisations: formal and informal. His suggestion was in accordance to what is expected from this phase – the refinement and elicitation of the concepts and relations. Therefore, his contribution led to revision, analysis and reconsideration of other concepts that would fall into this specialisation, for instance EO: Purpose, FEI EO: Strategic Purpose, and EO: Organisation Unit.

Participant 11 is the Head of Innovation and Future Tech and she experiences in her work the necessity to develop innovation capabilities in the team. Furthermore, she believes the innovation domain is not being sufficiently addressed by traditional undergraduate degrees. Therefore, for her, the knowledge representation offered by the FEI^{2}O would be a suitable training tool, as it provides a broad coverage of processes, activities, flows, decisions and roles in the FEI. Moreover, for this participant, the artefact is a useful tool for guiding the execution of FEI activities in an open innovation department. She also questioned about the integration of other supportive innovation tools by the FEI^{2}O, as her company uses Human-Centred Design. The FEI^{2}O supports the application of several methodologies and tools as illustrated in the sub-ontology FEI STAGE. Similarly, she questioned if the model enables the concept development, the service development and customer experiences, as these are vital issues for their business. Regarding the FEI roles, she considered them as a reliable representation of reality, however she missed the role of a facilitator.

An additional meeting to fine tune the artefact with 05 professors of entrepreneurship and innovation management occurred in March/2017. The main results show that the model is comprehensive. Nonetheless, it could benefit from a simplification.

The exploratory evaluation proceeded with the revised artefact and the following paragraphs explore the assessment of participants 12, 13 e 14.

Participants 12 and 13 assessed the model as complete. Their remarks concern the same issue, the stakeholder's child class. In other words, the representation of the specialisation of different stakeholders. Some minor inclusions were made to provide an ample variety of this concept.

Lastly, Participant 14, a professor of entrepreneurship, assessed the model as consistent. Participant 14, similar to participant 8, thinks it would be beneficial for entrepreneurs a tool that provides a hierarchical orientation and/or priorities paths concerning the use of FEI Activities. Moreover, he suggested the addition of the Lead-User as a Class Child of the User, considering the contribution of the User Driven Innovation.

The last three interviews assessed improvements of the artefact. No significant expansions, revisions or refinements were suggested in these interviews. Hence, the absence of further improvements led to the recognition that data saturation was achieved.

5.2 Validation Phase

An exploratory phase gives room to iterate and to refine the model and its fulfilment enables the next phase: the validation. Staab et al., (2001, p. 3) emphasises the need for a "stepwise construction and evaluation of the ontology". Therefore, it is responsibility of the validation phase to evaluate the final artefact as well as the competence questions.

Integration of end-users to evaluate the usability and the ability of the ontology to fulfil its purpose is vital to the further use of the ontology (Bilgin, Dikmen, & Birgonul, 2014; Bullinger, 2008). Hence, the next topic addresses the Focus Group participants profile.

5.2.1 Participants Profile

For this final phase of evaluation, participants were selected based on their familiarity with the beginning of the innovation process, whether in an academic or practical setting. A total of 19 participants were invited, with several dates proposed for the meeting. The winner date was the

one with a higher number of participants. The session took place in the Faculty of Engineering of the University of Porto, with 7 participants personally present and 02 via videoconference call.

Table 5-2 Focus Group Participant Profile

Gender	Expertise	Position
M	Medical Devices	Chief Enterprise Officer
M	Entrepreneur	Chief Quality Officer
M	Venture Capital	Chief Enterprise Officer
M	Integration Partnership Management	Director
M	R&D Management	R&D Group Leader
M	Software Engineer	Chief Technology Officer
M	Innovation & Gamification	Partner
M	Computer Science and Quantitative Methods	Assistant Professor
F	Graduate Discipline Coordinator of Entrepreneurship	Assistant Professor

The focus group session ocurred on 6th June 2017 and lasted 2 hours, from 11.00 am until 01.00. In the session, the participants were introduced to the artefact and to the evaluation procedures. The analysis roadmap used by the participants (judges) is provided in Appendix C.

5.2.2 Results of the Validation Phase

The main aspect of ontologies concerns its structure and ability to fulfil its intended purpose. Therefore, in a user integration evaluation process the choice of which criteria to apply for assessing the artefact is crucial. For Hevner et al., (2004) the process of evaluating a designed artefact demands the definition of proper metrics and the gathering and analysis of appropriate data. Table 5-3 presents available criteria to assess design science works.

Table 5-3 Possible Evaluation Criteria to be applied in the FEI²O validation phase

Author	**Suggested Criteria**
(Hevner et al., 2004b)	• Functionality, • completeness, • consistency, • accuracy, • performance, • reliability, • usability, • fit with the organisation, and, • other relevant quality attributes.
(March & Smith, 1995)	• Fidelity with real world phenomena, • completeness, • the level of detail, • robustness, and • internal consistency.
(Holsapple & Joshi, 2002)	• Comprehensiveness; • correctness, • conciseness, • clarity, and • utility.

The goal of the evaluation is to determine the progress of the research and how well the artefact works (Bilgin et al., 2014; March & Smith, 1995). The criteria were selected considering their representativeness to assess whether the ontology fulfilled or not its purpose. Therefore, the criteria selected were: Completeness; Comprehensiveness; Utility; Consistency and Understandability. The use of criteria provided an objective evaluation of the degree of success of the FEI Integrative Ontology. They were used to assess each of the following sub-ontologies:

- High-Level Sub-Ontology;
- FEI Purpose Sub-Ontology;
- Portfolio Planning & Management Sub-Ontology;
- FEI Stage Sub-Ontology;
- FEI Agile NCD Process Sub-Ontology; and
- FEI actors Sub-Ontology.

The answers to the evaluation criteria were analysed according to the Attribute Agreement Method, which is a quantitative approach suitable to evaluate the participants' answers. In this method, the participants' scores have been transformed from a Likert Scale to a Binary Scale, Table 5-4 shows the coding applied for the calculations. The work "Information Technology and Enterprise Integration for the Fuzzy Front End of Innovation" (Barradas, 2015) applied a similar approach to the evaluation of the COIN Ontology. To evaluate the COIN, the author considers $MV=1n\Sigma xi,xini=1\in[1;10]$, and each COIN sub-ontology was validated if $MV\geq 7$.

For the FEI^{2}O, the results consist of the averaged sum of all participants' evaluations, for each criterion (see Equation 5-1).

$$\text{Approval} = \frac{100}{n} \sum_{i=1}^{n} x_i$$

Equation 5-1 Attribute Agreement Equation

The results were calculated for each of the selected criterion as well as for each sub-ontology. The higher the score the greatest the certainty of the validation of the criteria for the evaluated sub-ontology. The FEI^{2}O follows the same rule applied by the COIN ontology, if Approval is ≥ 70, the sub-ontology was considered validated. The scores were also calculated globally, as the average approvals over all criteria.

Table 5-4 Evaluation coding

Likert Scale	**Binary Scale**
1 Strongly Agree 2 Agree	1
3 Neither Agree Nor Disagree (NAND) 4 Disagree 5 Strongly Disagree	0

The results for the **High-Level Sub-Ontology** are the following.

Table 5-5 Evaluation of the HIGH-LEVEL Sub-Ontology

Criteria	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**	**Validation**
Completeness	1	0	0	1	1	1	1	1	75.00%
Comprehensiveness	1	1	1	1	1	1	1	1	100.00%
Utility	1	1	0	1	1	1	0	1	75.00%
Consistency	1	0	1	1	1	1	1	0	75.00%
Understandability	1	1	1	1	1	1	1	1	100.00%
HIGH-LEVEL Sub-Ontology overall evaluation									85.00%

For the FEI High-Level Sub-Ontology, the criteria with the highest score were Comprehensiveness and Understandability with both approval scores of 100.00%. Completeness, Utility and Consistency presented 75.00%. For all five criteria, the approval score demonstrated a consistent level of validation of the artefact, overall 85.00% of approval.

Figure 5-2 illustrates the histogram of the High-Level Sub-Ontology scores. The “x” axis represents the Likert Scale and the “y” axis corresponds to the count of the participants’ scores for each criterion of evaluation. This figure shows the high level of approval for the evaluated criteria of the High-Level Sub-ontology. Furthermore, the only negative evaluation is registered for the Completeness criterion with one “Disagree” answer. Neither Agree Nor Disagree (NAND) are few in number through the five criteria with only 5 occurrences.

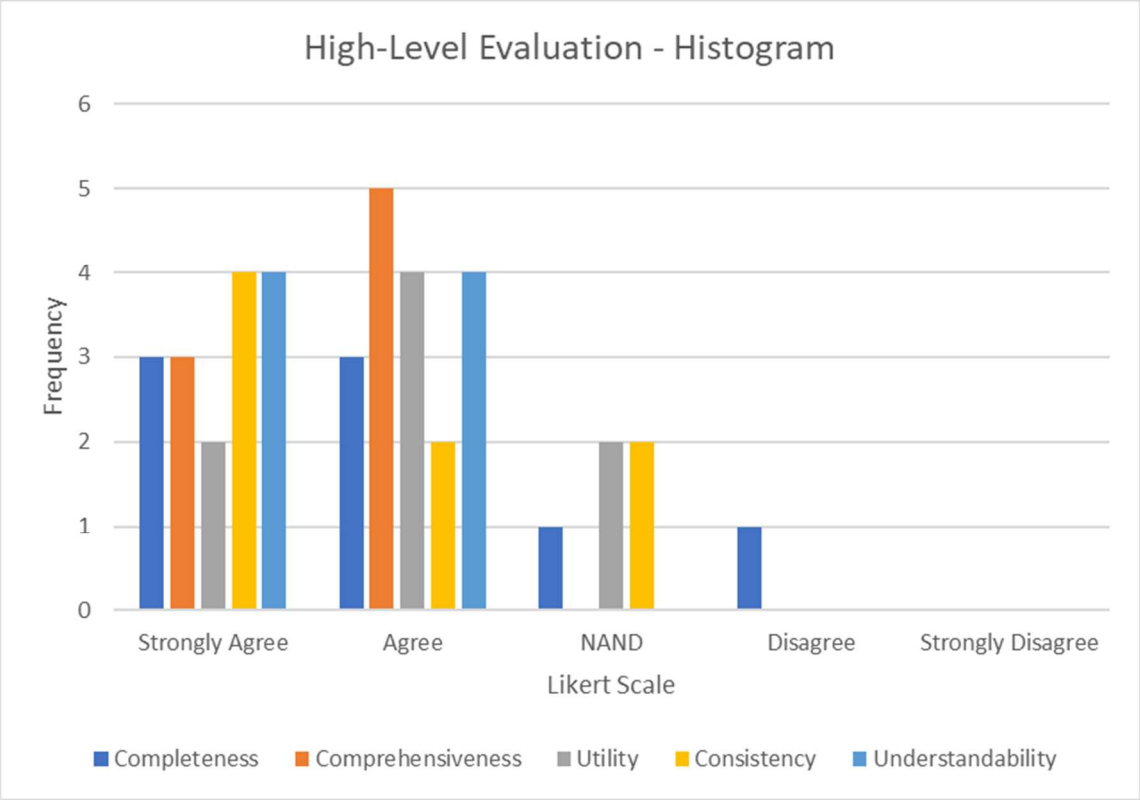

Figure 5-2 High-Level Evaluation Results

The next evaluation concerns the **FEI Purpose**. Table 5-6 illustrates the agreement analysis for this sub-ontology.

Table 5-6 Evaluation of the FEI PURPOSE Sub-Ontology

Criteria	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**	**Validation**
Completeness	1	0	1	0	1	1	1	1	75.00%
Comprehensiveness	1	0	1	0	1	1	1	1	75.00%
Utility	1	1	0	0	1	1	0	1	63.00%
Consistency	1	0	1	1	1	1	1	1	88.00%
Understandability	1	1	1	1	1	1	1	1	100.00%
FEI PURPOSE Sub-Ontology overall evaluation									80.00%

In this evaluation, Understandability stands out with 100.00% approval – the highest score. Furthermore, the Consistency criterion has an 88.00% approval; Completeness and Comprehensiveness both with 75.00%; and, the lowest score regards the Utility with 63.00%.

These totals provide and overall approval of 80.00%. A sufficient score to accept the validation of the Sub-Ontology FEI Purpose. Figure 5-3 offers an additional representation of the data.

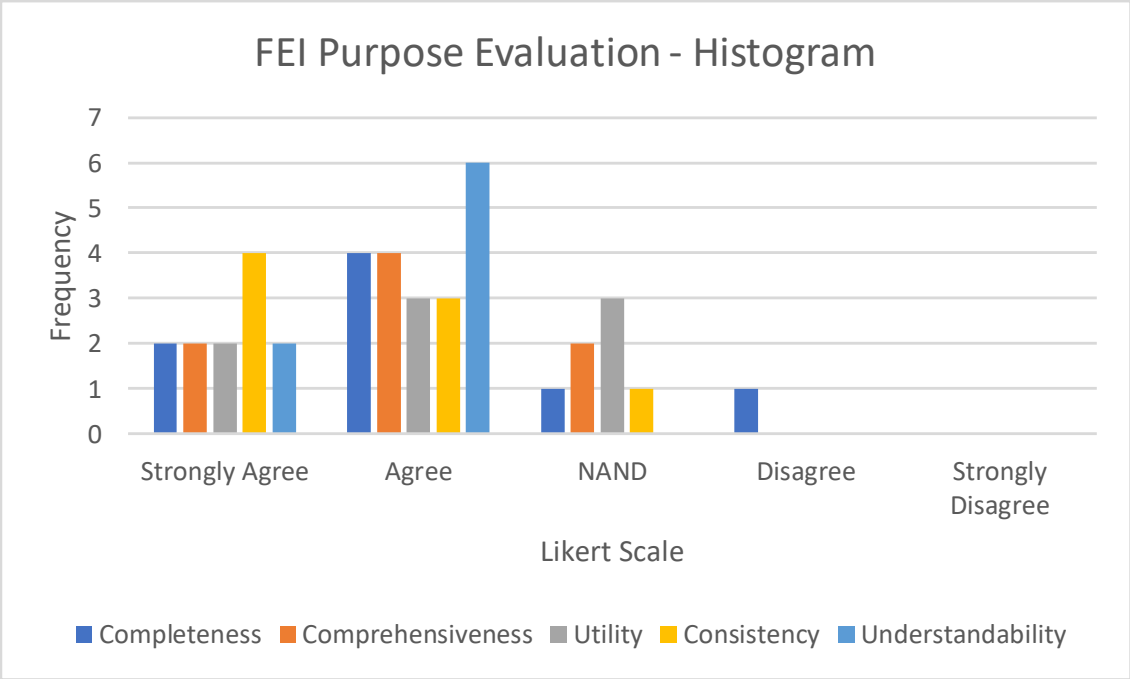

Figure 5-3 FEI Purpose Evaluation Results

The overall approval trend of the FEI Purpose indicates the successful validation of this sub-ontology, as there is only one occurrence for Disagree concerning the Completeness Criterion and no register of Strongly Disagree for any criterion. However, this sub-ontology presents the highest number of Neither Agree nor Disagree responses and these vary for each criterion. A participant neutral position may be a consequence of several hypotheses, for this research, it may be: a) difficulty in reading the FEI Purpose concept articulation in a UML representation; b) no familiarity with the concept; or even c) no opinion on the topic. The FEI Purpose is the more complex sub-ontology, and the representation illustrates the multitude of concepts, influences and relations present at the very beginning of the FEI.

Table 5-7 shows the evaluation results of the **Sub-Ontology Portfolio Planning & Management**.

Table 5-7 Evaluation of the PORTFOLIO PLANNING & MANAGEMENT Sub-Ontology

Criteria	J1	J2	J3	J4	J5	J6	J7	J8	Validation
Completeness	1	0	1	1	1	1	1	1	88.00%
Comprehensiveness	1	1	1	1	1	1	1	1	100.00%
Utility	1	1	0	0	1	1	1	1	75.00%
Consistency	1	1	1	1	1	1	1	0	88.00%
Understandability	1	1	1	1	1	1	1	1	100.00%
PP&M Sub-Ontology overall evaluation									90.00%

The overall approval of the PP&M sub-ontology is 90.00%. Two criteria presented scores of 100.00%, Comprehensiveness and Understandability. Furthermore, the lowest level of approval regards the Utility criterion with a score of 75.00%, still a high level of approval. Lastly, Figure 5-4 presents the PP&M evaluation data.

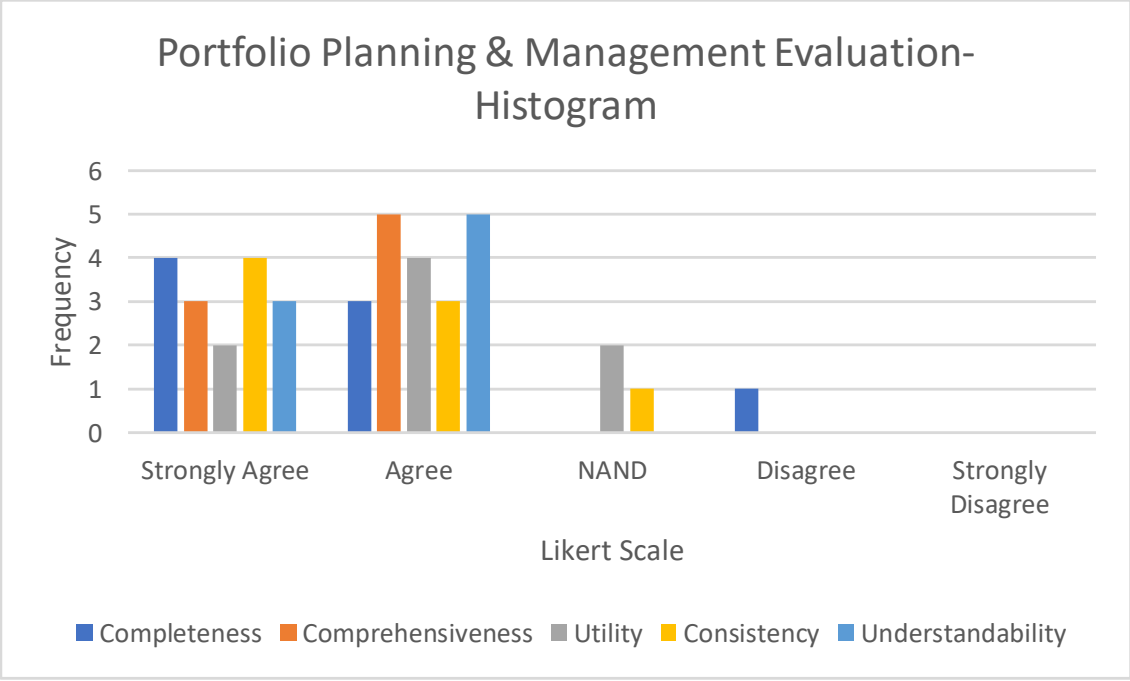

Figure 5-4 PP&M Evaluation Results

Table 5-8 presents the agreement analysis for the **FEI Stage** sub-ontology.

Table 5-8 Evaluation of the FEI STAGE Sub-Ontology

Criteria	J1	J2	J3	J4	J5	J6	J7	J8	Validation
Completeness	1	0	1	1	1	1	1	1	88.00%
Comprehensiveness	1	1	1	1	1	1	1	1	100.00%
Utility	1	1	0	1	1	1	1	1	88.00%
Consistency	1	1	1	1	1	1	1	0	88.00%
Understandability	1	1	1	1	1	1	1	1	100.00%
FEI STAGE Sub-Ontology overall evaluation									92.50%

The FEI Stage and the FEI Actors are the Sub-ontologies with the highest overall approval scores (see Table 5-11 p. 145). The FEI Stage received the highest score in two criteria, Comprehensiveness and Understandability. Nonetheless, Completeness, Utility and Consistency also presented higher levels of agreement, with 88.00% of approval each. The overall evaluation of this sub-ontology indicates an approval of 92.50%. Figure 5-5 shows the trend of these answers in Likert Scale.

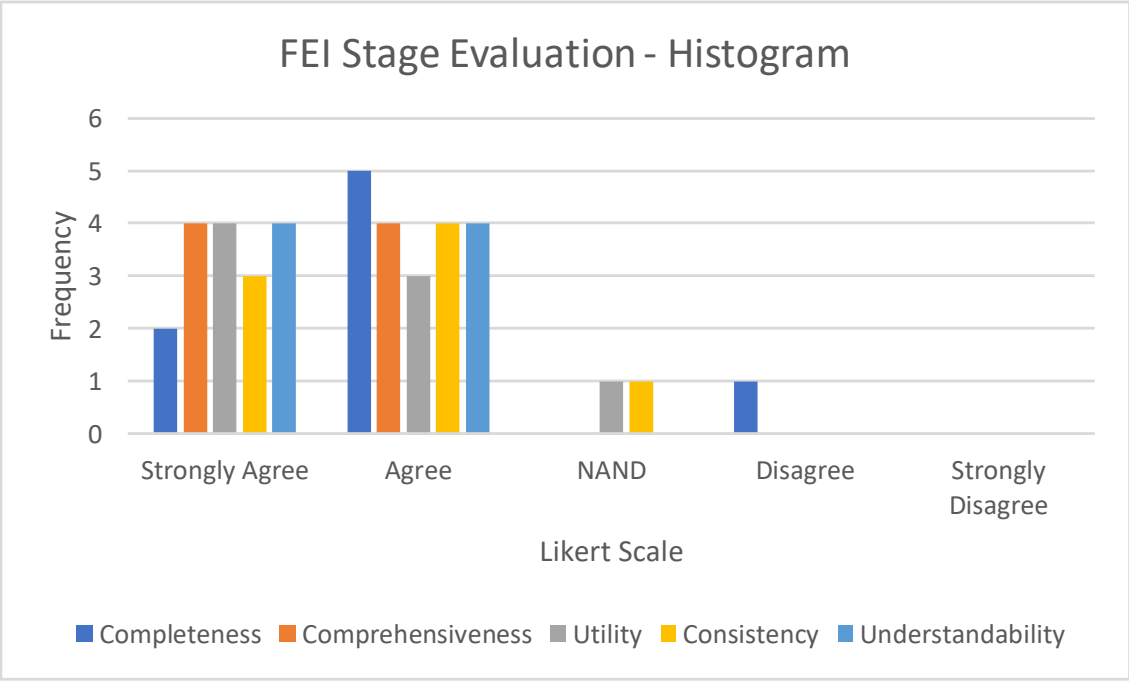

Figure 5-5 FEI Stage Evaluation Results

The approval trend is evident for the evaluation results of the FEI Stage Sub-Ontology. No record of Strongly Disagree for any of the evaluated criteria and only one Disagree for the assessment of Completeness. Moreover, Utility and Consistency received 01 NAND answer each, while the overall answers concentrate in Agree or Strongly Agree.

Table 5-9 presents the **FEI Agile NCD** evaluation. The results of this Sub-Ontology remark a total of 82.50% of approval. All five criteria received scores equal or above the mark of 75.00%, and Figure 5-6 illustrates the evaluation data.

Table 5-9 Evaluation of the FEI AGILE NCD Sub-Ontology

Criteria	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**	**Validation**
Completeness	1	0	1	1	1	1	1	1	88.00%
Comprehensiveness	1	0	1	1	1	1	1	1	88.00%
Utility	0	1	0	1	1	1	1	1	75.00%
Consistency	1	0	1	1	1	1	1	0	75.00%
Understandability	1	0	1	1	1	1	1	1	87.50%
FEI AGILE NCD Sub-Ontology overall evaluation									82.50%

The FEI AGILE NCD sub-ontology has only one Disagree answer concerning the Utility criterion (see Figure 5-6). NAND answers registered six incidences, with one in Understandability, one in Comprehensiveness; and two each in Utility and Consistency. This is a high number compared to the other sub-ontologies. Furthermore, there are no Strongly Disagree answers for any criteria. In sum, the overall trend demonstrates the successful validation of this sub-ontology.

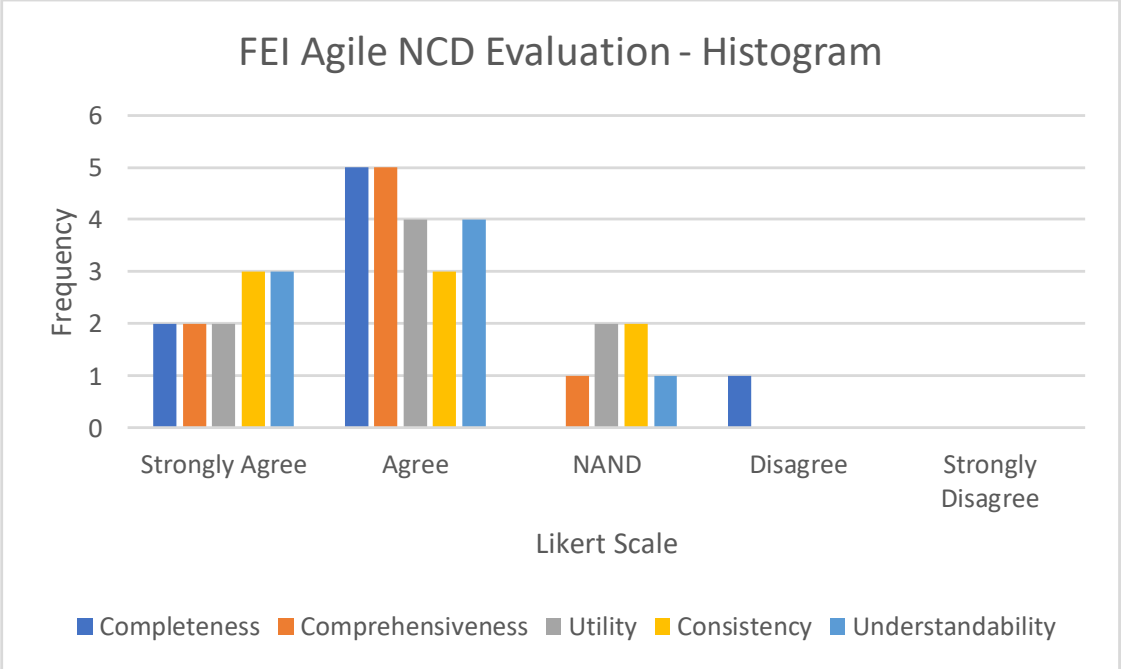

Figure 5-6 FEI NCD Evaluation Results

The last sub-ontology evaluated is the **FEI Actors**. This sub-ontology together with the **FEI Stage** show the most optimistic results. Table 5-10 illustrates its agreement analysis.

Table 5-10 Evaluation of the FEI ACTORS Sub-Ontology

Criteria	**J1**	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**	**Validation**
Completeness	1	0	1	1	1	1	1	1	88.00%
Comprehensiveness	1	1	1	1	1	1	1	1	100.00%
Utility	1	1	0	1	1	1	1	1	88.00%
Consistency	1	0	1	1	1	1	1	1	88.00%
Understandability	1	1	1	1	1	1	1	1	100.00%
FEI ACTORS Sub-Ontology overall evaluation									92.50%

The results show a prominent approval score of 92.50%. Therefore, FEI Actors and FEI Stages hold the highest approval scores. The highlights of this evaluation concern Comprehensiveness and Understandability, which scored 100.00% each. Moreover, Consistency, Completeness

and Utility had only one Disagreement, among eight participants, for each of these criteria. Figure 5-7 shows the evaluation results for this sub-ontology.

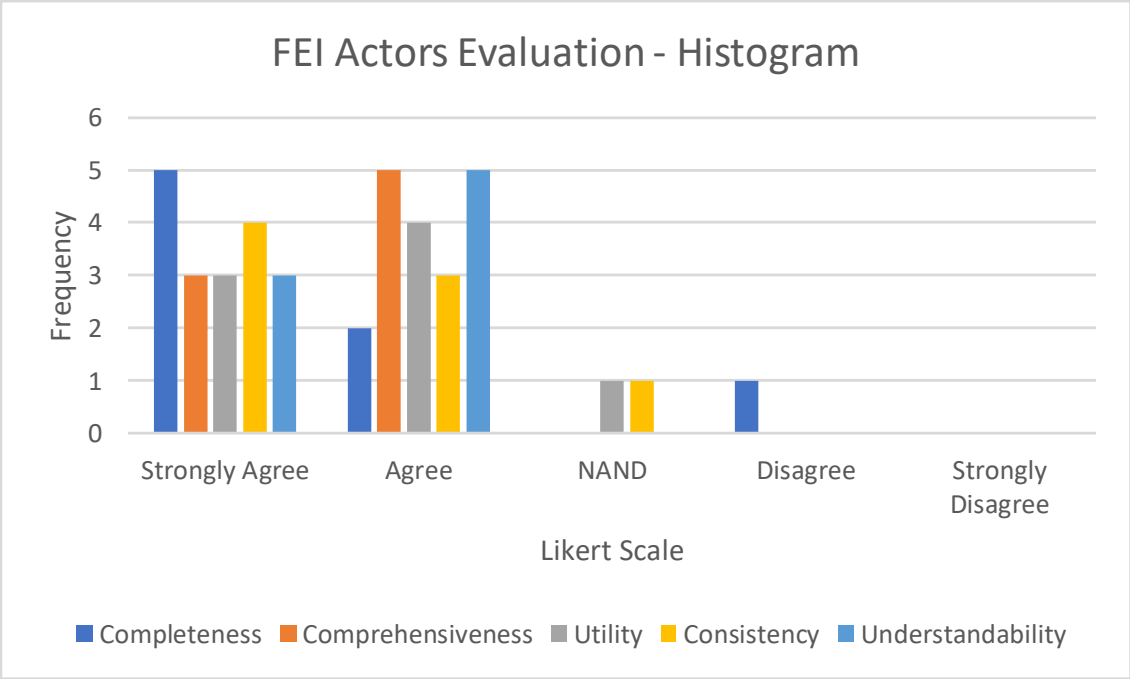

Figure 5-7 FEI Actors Evaluation Results

Figure 5-7 depicts some minor dispersions, but the overall trend is approval. For instance, one Disagree answer expressed for Completeness, and one Neither Agree Nor Disagree answer for each one of Utility and Consistency. Lastly, Strongly Agree and Agree represent the highest concentration of answers for all criteria.

A global evaluation is welcomed to present the results for each of the six sub-ontologies. Therefore, Table 5-11 shows the overall results. The calculations consist of the simple average across all sub-ontologies.

Table 5-11 Global Evaluation Results FEI Integrative Ontology

Sub-ontology	**Score Method A**
High-Level	85.00%
FEI Purpose	80.00%
Portfolio Planning & Management	90.00%
FEI Stage	92.50%
FEI Agile	82.50%
FEI Actors	92.50%
Global evaluation	**87.10%**

The FEI^{2}O was successfully validated with an approval of 87.10%. Participants also shared their thoughts on the FEI^{2}O. These comments concern appraisals and general observations. Here are some of their remarks:

- A participant raised the question of how to smooth the translation of the ontology into a practical approach, given the overwhelming nature of the FEI is a concern for scholars and practitioners.
- A participant questioned how the model would adapt to start-up, small, medium and even big enterprises.
- Another participant expressed concern on who should decide when a final concept is achieved.
- Congratulations on the job, as the work is an opportunity to link innovation and business.
- A participant emphasised the need of Strategic Planning to have a disruptive mindset to enable the potentialities of innovation.
- An interesting comment regards the analogy of the Big Bang theory to the FEI^{2}O, as it aims to depict a complex phenomenon. This participant further emphasised the need to balance the excessive generalisation, as, in his point of view, too much theory makes us sterile. He encourages the work to move forward aiming at creating and characterising a comprehensive methodology, hence offering an adequate tool to help entrepreneurs, especially in what concerns support for the decision-making process.

- Another participant envisions the FEI^{2}O Canvas as a modular tool, with optional: building blocks, phases and processes. This comment stems from the business run by this participant, that is Technology, Information and Communication (TIC) field. For him, TIC companies have a PP&M shorter than companies from traditional sectors.
- One participant thought important to emphasise that there is already an FEI Canvas® and the need to look at it in order to have a comparative analysis. As a reply to this comment, it was mentioned that, preliminary to the FEI^{2}O development, other FEI works were subject to an exploratory analysis, concerning their coverage and benefits, including the cited canvas.

5.3 Participants' evaluation of the Competence Questions

The evaluation process also comprises the assessment of the Competence Questions. Therefore, the participants evaluated if the Competence Questions were answered by the FEI Integrative Ontology. Their responses can be seen in Table 5-12.

Table 5-12 Answers for the Competence Questions

Competence Questions	Yes Responses	No Responses
1. Does the ontology allow the identification of the knowledge domains present in the FEI?	8	0
2. Which are the outcomes (results) of the FEI Integrative Ontology?	6	2
3. Which processes unfold in the context of the FEI Ontology?	7	1
4. Which are the stages related to the New Concept Development?	8	0
5. Which are the outputs of the FEI Agile New Concept Development?	6	2
6. Who are the actors in the FEI?	8	0
7. Which are the roles played by FEI actors?	8	0

The Competence Questions evaluation were assessed according to the answers provided by the participant during the Focus Group session, no changes or late submissions were allowed. This protocol ensured a homogeneous treatment for all the data by avoiding that participants forget the content under evaluation or likely future misunderstandings.

The results show that four questions received total agreement, for instance, CQ1; CQ4; CQ6 and CQ7. Furthermore, CQ5 and CQ3 received two and one negative responses each. CQ2 evidences the necessity of presenting the FEI Integrative ontology outputs, due to the large coverage of the work. The same observation is valid for CQ5, given that this question received two "No" responses. However, the researcher did not present any of the answers to the competence question in the Focus Group session, in order to avoid any bias.

The overall assessment of the participants' evaluation indicates that the competence questions were answered by the FEI^{2}O.

5.4 Conclusion

The procedures adopted to refine and assess the ontology aimed at strengthening the work, by means of a comprehensive evaluation process with an exploratory and a validation phase. The previous sections presented an overview of the efforts applied to evaluate the proposed artefact. The evaluation process comprised:

a) An Exploratory Phase.
    a. Exploratory concept elicitation with domain experts, to evaluate both the terms and relations implemented by the FEI Integrative Ontology, on a sub-ontology basis; and,
    b. Revision, expansion and refinement of the artefact based on feedback. The exploratory phase iterated the model according to the domain expert needs.
b) A Validation Phase.
    a. Sub-ontology validation based on an evaluation roadmap contemplating five criteria (completeness, utility, comprehensiveness, understandability, consistency)
    b. The participants evaluated whether the Competence Questions were answered by the FEI^{2}O.
c) Competence Questions evaluation.
    a. Analysing in detail each of the FEI^{2}O sub-ontologies; and

b. Quantitative determining if the Competence Questions were answered by the FEI^{2}O.

This evaluation setting followed the recommendations of Staab et al. (2001), which advocates for an iterative evaluation process and analysis of competence questions. The two-phase approach (exploratory and validation) provided a consistent and comprehensive method to evaluate the ontology. The interviews with the experts, in the exploratory phase, and the feedback from the participants, of the validation phase, presented a successful validation of the FEI^{2}O. Moreover, the Attribute Agreement Analysis revealed a global approval of 87.01% and the participants' evaluation indicates that the competence questions were answered by the FEI^{2}O. Therefore, there is sufficient evidence to claim a successful validation of the work.

Chapter 6 Ontology Applications and Discussion

The FEI Integrative Ontology (FEI^{2}O) provides a formal domain model with concepts and relations validated and accepted by domain experts and end-users. FEI^{2}O may be used and applied in different settings, thus meeting the demands set by Winter (2008, p. 472): "while theory building is important and necessary to explain real-world phenomena, this knowledge also needs to be put into action in order to solve real-world problems".

The FEI^{2}O provides a comprehensive and integrative knowledge representation supported by the modelling capability of an ontology. It shapes the body of knowledge around the FEI, making it useful as an effective basis to organise and manage FEI processes as well as a framework relevant for future FEI research. Consequently, the by-products of the FEI^{2}O comprise a varied range of applications, some of which could benefit from further development. The next sections explore an analysis of the FEI^{2}O and the Main FEI Reference Models and some of the FEI^{2}O applications.

6.1 The FEI^{2}O and the Main FEI Reference Models

The main FEI reference models are not ontologies, their knowledge representation is limited, whereas the FEI^{2}O, as an ontology, aims at being a domain model, hence providing a description of a domain regarding: concepts, properties and concepts relations. Nonetheless, they provide important and seminal contributions to the FEI, and their relevance means that it makes sense to see how these models are projected into the FEI^{2}O. It is in this context that Table 6-1 provides a comparative analysis that helps to understand the coverage of the FEI^{2}O compared to the main FEI reference models. In order to provide a more concise view, some FEI^{2}O specialisations were omitted from this table. These are BMO: Tangible Assets, BMO:

Intangible Assets, BMO: People Based Skills, EO: Strategic Goal, EO: Tactic Goal, and EO: Operational Goal. These specialisations inherit from BMO: Resources (Figure 4-5 p.107) and EO: Goals (Figure 4-3 p. 100). These higher level concepts are included in the analysis.

Table 6-1 makes this comparison by classifying each reference model concept as:

- 0 for non-existing element in the reference model,
- 1 for element mentioned in the reference model,
- 2 for element described in the reference model, and
- 3 for modelled element.

Table 6-1 Cross-analysis Main FEI Reference Models and FEI^{2}O

	Concepts present in the sub-ontology	**Khurana & Rosenthal**	**Koen et al.**	**Cooper**	**Reid and De Brentani**
FEI Purpose *Focus on Opportunity*	Source of Opportunity	0	1	0	0
	Opportunity Recognition	0	1	3	1
	Opportunity Confidence	0	0	0	0
	Opportunity	3	3	2	3
	CO: requirement	2	2	3	1
	CO: threat	0	2	0	0
	CO: strength	0	1	0	0
	CO: weakness	0	0	0	0
	CO: problem	2	2	2	3
FEI Purpose	Opportunity	3	3	2	3
	FEI EO: strategic purpose	0	0	2	0
	EO: strategic planning	3	2	3	3
	[Business] EO: purpose	2	2	2	0
	CO: criterion	2	2	3	2
	EO: goal	1	2	3	1
	EO: mission	0	0	3	0
	EO: vision	3	0	0	0

	Concepts present in the sub-ontology	**Khurana & Rosenthal**	**Koen et al.**	**Cooper**	**Reid and De Brentani**
Portfolio Planning & Management (PP&M)	FEI EO: strategic purpose	0	0	3	0
	Portfolio planning & management	2	2	3	0
	Portfolio planning	3	2	3	0
	Portfolio management	2	2	3	0
	Market scanning	3	2	3	3
	Technology scanning	3	2	3	3
	Capability development	2	2	1	0
	EO: Strategic planning	3	3	1	3
	Product & portfolio strategy	3	2	0	0
	Technology roadmap	0	2	0	0
	Product roadmap	0	2	2	0
	Organisational factors	3	3	1	2
PP&M *Focus on Organisational Factors*	Organisational factor	3	3	1	2
	Structure	3	2	0	1
	Senior management involvement	2	3	3	1
	Team and collaboration	2	2	3	2
	Culture	1	3	2	0
	Resources	3	2	3	3
	Capability	2	2	1	0
	Capability development	3	0	0	0
	Partnership	1	2	3	0
FEI Agile New Concept Development	FEI Agile NCD	0	0	3	0
	A: Agile method	0	0	0	0
	FEI EO: Strategic purpose	0	0	3	0
	Portfolio planning & management	2	2	3	0
	FEI stage	3	0	3	0
	FEI iteration	0	0	0	0
	Iteration information	0	0	0	3
	Build	0	0	3	0
	Measure	0	0	3	0
	Learn	0	0	3	0
	New Concept	3	3	3	3
FEI Stage	Preliminary opportunity identification	3	3	3	3
	Product concept development	3	3	3	1
	Feasibility and project planning	3	2	3	1
	Business model development	0	0	0	0

	Concepts present in the sub-ontology	Khurana & Rosenthal	Koen et al.	Cooper	Reid and De Brentani
FEI Actors	EO: actor	1	1	1	2
	EO: activity	2	2	3	2
	Stakeholder	2	2	1	0
	BMO: people based skill	0	0	0	2
	EO: organization unit	1	2	0	1
	CO: position	0	0	0	0
	CO: organisation	3	1	1	1
	EO: machine	0	0	0	0
	CO: organisational role	3	2	2	3
	T-shaped specialist	0	0	0	0
	Leadership role	2	3	3	1
	Innovator role	0	0	0	0
	Facilitator	0	0	2	2
	Gatekeeper	0	1	3	3
	Sponsor	0	1	0	2
	Champion	0	1	0	3

0 non-existing element; 1 mentioned element; 2 described element; 3 modelled element

In this comparative analysis, the table key (0,1, 2 or 3) classifies how these concepts are covered by the main FEI reference models. However, this is not an in-depth analysis revealing the different approaches developed by each author. Nonetheless, it offers a general view of the topics addressed in the FEI. As result of this analysis, some remarks could be made:

- For the sub-ontology FEI-Purpose, there is a lack of attention in the main FEI reference models to concepts such as: Source of Opportunity; Opportunity Recognition; Opportunity Confidence; CO: threat; CO: strength; CO: weakness; FEI EO: strategic purpose; EO: mission; and EO: vision.
- For the sub-ontology PP&M, the models provide a homogeneous approach for concepts related to the portfolio planning. However, important concepts related to the necessary alignment of Portfolio Planning & Management (PP&M) and Product & Portfolio Strategy (P&PS) received less attention, for instance: Product & Portfolio Strategy; Technology Roadmap; and, Product Roadmap.

- For the sub-ontology PP&M focusing on Organisational Factors, the highlight concerns the lack of attention to the concept Capability Development. Moreover, Organisational Factor received a varied degree of attention through the models. Table 6-1 illustrates that the works of Khurana and Rosenthal (1997, 1998) and Koen et al. (2002) offered a more comprehensive approach than the approach of Cooper (2008) and Reid and De Brentani (2004). Nonetheless these works still lack concept modelling as depicted by the table.
- For the sub-ontology Agile NCD, the work of Cooper (2008) shows some modelling of agile concepts, such as, "build-test-feedback-and-revise'' iterations. Furthermore, the work of Koen et al. (2002) although with an iterative design, does not deepens into the set of activities for an agile development.
- For the sub-ontology FEI Stage, the aim of the model of Reid and De Brentani (2004) was to explore the information flow/structure, therefore it is not suitable for a detailed comparison. The other models at some degree, provide stages for dealing with opportunity, concept development, feasibility and project planning, even if not with the same name of FEI Stages. However, none of these models offer a stage including the business model development.
- For the sub-ontology FEI Actors, Actors and roles present a sparse dispersion across the main FEI reference models. Consequently, the contribution of the FEI^2O is valuable, as it provides an extensive representation of FEI Actors and roles.

Table 6-2 offers a summary view of the previous table and shows the different coverage provided by each of the main FEI reference models:

- The FEI Purpose concepts focused on Opportunity has a high number of hits in 0 (non-existing element) revealing that there are few modelled elements.
- The FEI Purpose in itself received a more diverse approach by the different models. It should be highlighted the Stage-Gate model, with the higher number of described and modelled elements.

- The PP&M has a more uniform approach, there is a balance in terms of described and modelled elements ("3", higher ranking in the proposed classification). PP&M focused on Organisational Factors displays a similar behaviour.
- The FEI Agile NCD coverage is dominated by the incidence of non-existing element ("0"). This is evident in all four models.
- The sub-ontology FEI Stage is mostly covered by the main FEI models. However, none of these models offers a total representation of the four stages proposed by this sub-ontology.
- Lastly, the concepts in the sub-ontology FEI Actors received less attention by the main FEI reference models as the non-existing element ("0") and the mentioned element ("1") are preponderant.

Table 6-2 Summary analysis FEI^{2}O and Main FEI Reference Models

	Totals	**Khurana & Rosenthal**	**Koen et al.**	**Cooper**	**Reid and De Brentani**
FEI Purpose Focus on Opportunity	0 non-existing element	6	2	5	5
	1 mentioned element	0	3	0	2
	2 described element	2	3	2	0
	3 modelled element	1	1	2	2
	Total	**9**	**9**	**9**	**9**
FEI Purpose	0 non-existing element	2	3	1	4
	1 mentioned element	1	0	0	1
	2 described element	2	4	3	1
	3 modelled element	3	1	4	2
	Total	**8**	**8**	**8**	**8**
PP&M	0 non-existing element	3	1	2	9
	1 mentioned element	0	0	3	0
	2 described element	3	9	1	1
	3 modelled element	6	2	6	2
	Total	**12**	**12**	**12**	**12**
PP&M Organisational Factors	0 non-existing element	0	1	2	4
	1 mentioned element	2	0	2	2
	2 described element	3	5	1	2
	3 modelled element	4	3	4	1
	Total	**9**	**9**	**9**	**9**
FEI AGILE NCD	0 non-existing element	8	9	3	9
	1 mentioned element	0	0	0	0
	2 described element	1	1	0	0
	3 modelled element	2	1	8	2
	Total	**11**	**11**	**11**	**11**

	Totals	Khurana & Rosenthal	Koen et al.	Cooper	Reid and De Brentani
FEI STAGE	0 non-existing element	1	1	1	1
	1 mentioned element	0	0	0	2
	2 described element	0	1	0	0
	3 modelled element	3	2	3	1
	Total	**4**	**4**	**4**	**4**

	Totals	Khurana & Rosenthal	Koen et al.	Cooper	Reid and De Brentani
FEI ACTORS	0 non-existing element	9	6	8	5
	1 mentioned element	2	5	3	3
	2 described element	3	4	2	5
	3 modelled element	2	1	3	3
	Total	**16**	**16**	**16**	**16**

Table 6-3 offers a global view on the previous table. This new table helps to see the global proportion of the results. This visualisation depicts the attention given by the main FEI reference models to concepts addressed by the FEI^{2}O. There are some remarks concerning this global high-level analysis referring to:

- the high-incidence of non-existing elements ("0");
- the low percentage of modelled elements ("3") by each Model;
- and the number of concepts in each model that were non-explored, represented by elements that were mentioned ("1") described elements ("2"), but not modelled ("3").

Table 6-3 Global High-level Analysis FEI^{2}O and Main FEI Reference Models

Totals	Khurana & Rosenthal	Koen et al.	Cooper	Reid and De Brentani
0 non-existing element	42%	33%	32%	54%
1 mentioned element	7%	12%	12%	14%
2 described element	20%	39%	13%	13%
3 modelled element	30%	16%	43%	19%
Total	**100%**	**100%**	**100%**	**100%**

The main benefit of the FEI^{2}O is to provide a formal reference model and a common vocabulary, by balancing the differences and addressing the shortcomings of the main FEI

Reference Models. This analysis provides to researchers in the field with the positioning of the FEI²O with respect to these well-known and most referenced models.

6.2 FEI²O Canvas

One of the applications of the ontology is the FEI²O Canvas, which is the result of a first iteration into the development of a comprehensive canvas for the FEI and, as a result of that, has not yet been through any evaluation process. The FEI²O Canvas reflects the building blocks of the FEI Integrative Ontology, which are: Opportunity issues; the FEI Strategic Purpose; the FEI Stage; the Portfolio Planning & Management and the FEI Agile NCD. The FEI Actors is a basal sub-ontology present throughout the FEI. And the High-Level sub-ontology is the actual Canvas, depicting the relationship among the main concepts. Figure 6-1 illustrates this canvas.

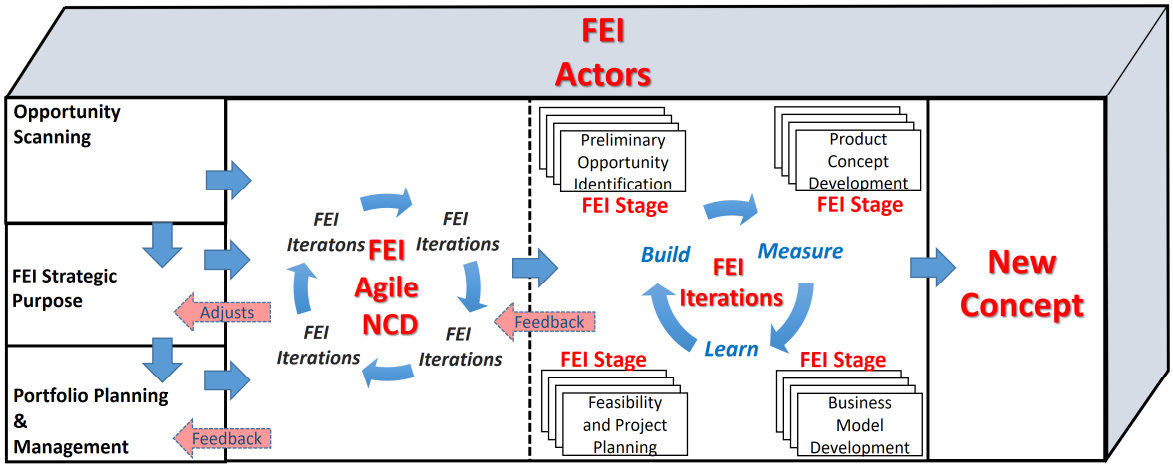

Figure 6-1 FEI²O Canvas

The opportunity scanning block represents a moment when the entrepreneur or other FEI actor is looking for internal and external sources of opportunity (Table 2-1, p. 41). These Sources of Opportunity will enable the Recognition of an Opportunity and will provide the entrepreneur with Confidence concerning the Opportunity identified. As a reminder, an opportunity is a "business or technology gap (…) that exists between the current situation and an envisioned

future" (Koen et al., 2002, p. 7). Therefore, an opportunity can answer questions such as Requirement, Threat, Strength, Weakness and Problems. The opportunity concept helps an entrepreneur, an innovation manager or any given actor involved in the FEI process to take advantage of an opportunity.

Also, the opportunity will drive the definition of an FEI Strategic Purpose. This purpose contributes to the Portfolio Planning & Management (PP&M) and it feeds the FEI Agile NCD. This agile process that goes from Opportunity Identification to Concept Definition encompasses iterative loops based on the following principles: Build, Measure and Learn.

The FEI Agile NCD comprises the FEI iterations (with its iterative loops) and these iterations may contain several FEI Stages (with its activities).

The FEI Agile NCD block is also responsible to adjust the FEI Strategic Purpose and to feedback to the Portfolio Planning & Management (PP&M). The latter was unfolded by the Product & Portfolio Strategy (P&PS). Both PP&M and P&PS consider internal and external factors to the organisation, whether the organisation is formal or informal.

The move from Opportunity Scanning to the New Concept requires an FEI Agile NCD process. Moreover, it enables the dynamic configuration of the FEI activities. The nature of FEI activities may or may not be sequential. However, projects must pass through logical phases of development, even if they must repeat an activity or regress through iterative loops.

These FEI iterations may occur as many times as required to develop a New Concept. Eventually, this FEI iteration process may adjust the FEI Purpose. These iterations may offer feedback to the Portfolio Planning & Management. The FEI Agile NCD will occur reaching a new concept, namely through prototypes.

Many actors join the FEI process, some may be involved throughout its entirety, while others may have particular responsibilities. The FEI Integrative Ontology considers as actors Stakeholders, People Based Skill, an Organisation Unit or even Machines.

The High-Level Sub-Ontology (Figure 4-18, p. 125) illustrates the engagement association between FEI ACTORS and FEI AGILE NCD. Storbacka et al., (2016 p. 3012) characterise

actor's dispositions to engage "as a capacity of an actor to appropriate, reproduce, or potentially innovate upon connections in the current time and place, in response to a specific past and/or toward a specific future". Therefore, Actors Engagement "is defined as both the actor's disposition to engage, and the activity of engaging in an interactive process of resource integration within a service ecosystem" Storback et al. (2016, p. 3008). This definition elaborates on the attitude of the actor and his/her actions towards an end to be accomplished and it represents the criticality of engagement necessary for an FEI actor in the FEI process.

The organisational roles vary from a T-Shaped Specialist to a Leadership Role. Special emphasis may be given to the Innovator Role, which can be performed by Facilitators, Gatekeepers, Sponsors or Champions.

The FEI^{2}O canvas starts with the opportunity scanning due to the triggering role of an opportunity. Innovative opportunities consist of ''the possibility to realize a potential economic value inherent in a new combination of resources and market needs, emerging from changes in the scientific or technological knowledge base, customer preferences, or the interrelationships between economic actors''(Holmén, Magnusson, & McKelvey, 2007, p. 37). When they follow an innovative opportunity, FEI Actors identify, act upon and realise the potential inherent in an idea. Moreover, innovative opportunities abide by the following criteria:

a) They bring an economic value for someone;
b) They hold the potential to mobilise resources needed to realise the opportunity;
c) The actor pursuing the opportunity appropriates at least some of the generated economic value.

The FEI^{2}O Canvas addresses this dynamic, as follows:

a) The FEI Purpose must be aligned with the EO: Business Purpose and they are evaluated according to some CO: Criteria. In this case, they are still in their embryonic form, hence they may be assessed through the possibilities of future economic value;
b) The notion of resources is answered with the alignment between the Portfolio Planning & Management (PP&M) and the Portfolio and Product Strategy (P&PS). Resources is

a specialisation of Organizational Factor. The latter impacts on the PP&M and enables the P&PS. Hence, both accomplishments, the PP&M and the P&PS, need resources.

c) The possibility to appropriate the economic value is potentialised by the application of the FEI Agile NCD, as this process produces a New Concept.

The description of the set of steps of the FEI^{2}O canvas exemplifies how the FEI process unfolds, from the early identification of an opportunity to the definition of a concept. The analysis of the innovative criteria is a theoretical support that illustrated the manner by which the FEI^{2}O Canvas conceptually complies with the innovative opportunities criteria (Holmén et al., 2007).

6.3 Instantiation

The instantiation of the FEI^{2}O is of importance to prove the feasibility of the artefact developed, considering that artefacts must accurately represent the business and technology environments used in the research (Hevner et al. 2004). Thereby, this section explores the instantiation of the proposed FEI Integrative Ontology considering two applications: a) the Jersey Square, a well-known Lean Start-up case; and, b) mobLee a Brazilian company of the user experience industry.

Instantiations represent the accomplishment of an artefact in its environment. In Design Science research "instantiations are problem specific by definition, instantiation design is always solution engineering; it may include adaptation of situational (reference) models, situational methods, and situational constructs" (Winter, 2008, p. 471). Hence, artefact instantiation demonstrates the feasibility of the designed artefact (Riedl et al., 2009).

6.3.1 The Jersey Square Case

Lean principles have become important for general management, non-manufacturing contexts as well as other areas, such as IT development. More recently, the lean start-up approach has enjoyed widespread popularity among entrepreneurs and managers (Costa, 2014. p. 53).

The instantiation of the ontology offers a contribution to demonstrate the utility of the FEI^{2}O, by framing a lean start-up case, this was selected because of its widespread use as innovation method for start-up companies (Ries, 2011). The "Jersey Square" case was chosen to be instantiated by the FEI^{2}O. Table 6-4 presents the timeline of the case scenario, developed for the "Jersey Square Case" from Steve Blank at the Lean Launch Pad, Columbia Business School, which is available online:

> *The source files of the case are available at https://www.slideshare.net/sblank/team-i-jersey-squarefinalv2. The video "JerseySquare Value Proposition - How to Build a Startup" is found in the Udacity Chanel available at https://www.youtube.com/watch?v=q5y30Da7amE .*

Table 6-4 The Jersey Square Case Timeline

The "Jersey Square: The Netflix of Licensed Sports Jersey" consists of the proposal of a rental service for professional sports jerseys.
Day 1 – The team developed their Business Model Canvas based on their initial business hypothesis. They gathered valuable insights to update the BMC, during the Customer Discovery Phase (get out of the building).
Day 2 – After the Customer Discovery, they updated the BMC, which brought the Customer Segments, Customer Relationships and Revenue Stream blocks were updated.
Day 3 – The team got out of the building again and performed another Customer Discovery Phase to fine tune their BMC. Consequently, they expanded their Customer Segments and the Value Proposition.
Day 4 - Another Customer Discovery, as they go outside the building again. This iteration provided the inputs to adjust their Revenue Stream. This round also adjusted the Customer Relationship to include Social Media.
Day 5 – They adapted the Revenue Stream by including more options, in line with customer needs.

Figure 6-2 shows the instantiation of the Jersey Square case considering the FEI High-Level Sub-Ontology. The High-Level Sub-Ontology offers a summarised view of the key relationships and concepts comprised in the FEI. It does not offer a detailed view of the dynamic occurred in the FEI process. The FEI Agile NCD Sub-Ontology provides this view and it is illustrated in Figure 6-3. Nonetheless, this partial instantiation offers a high-level view of the five days activities of the team. Through the iteration process of the «Customer

Discovery Activities» they obtained information regarding the «Customer Segments Discovery Activities», «Customer Discovery Relationships Activities» and «Revenue Stream Discovery Activities» for a fine-tuning of their initial Business Hypothesis «A rental service for professional sports jerseys» more in line with their customer pains and gains.

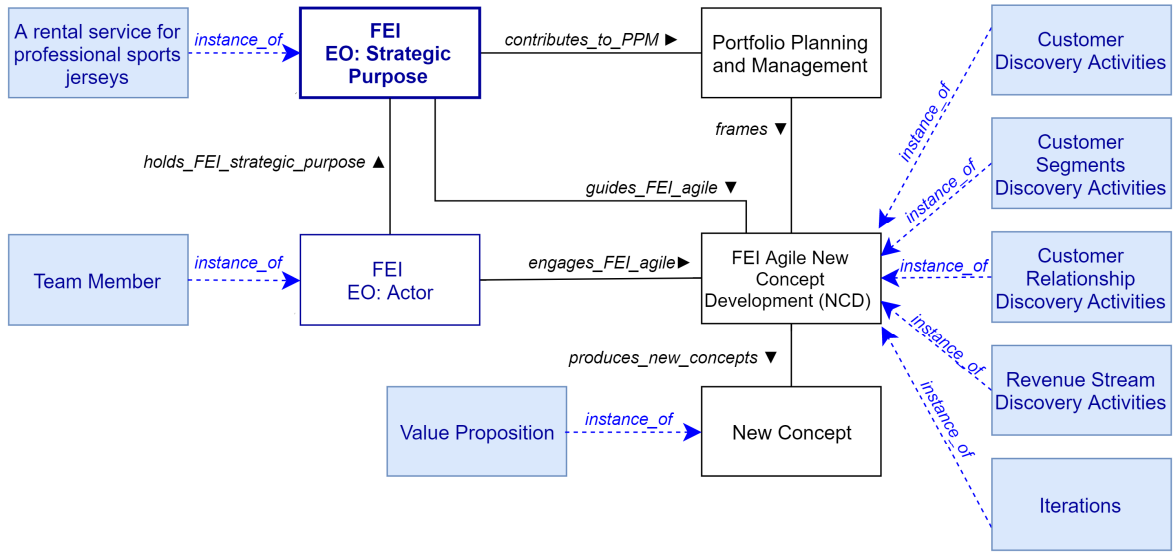

Figure 6-2 Partial Instantiation of the High-Level Sub-ontology in the context of the Jersey Square case

Figure 6-3 illustrates the Partial Instantiation of the Agile NCD Sub-ontology in the context of the Jersey Square case. Central to this is the iterative process with constant information collections by "going out of the building". These iterations involve «Build Experiment» and «Gather Experiment Data » as instances of BUILD, «Gather Experiment Results» as instance of MEASURE, and «Interpret Experiment results» as instance of LEARN. By performing experiments out of the building, the initial FEI EO: STRATEGIC PURPOSE may be updated or a new opportunity may trigger a new instance of an FEI AGILE NCD. The "Jersey Square Case" required five iterations until reaching a final «Value Proposition», an instance of the NEW CONCEPT. In these iterations, the «Business Model Canvas Versions» an instance of the FEI STAGE was updated several times. In sum, the application case used the Lean Start-up methodology and simultaneously develop the Product/Service, «Value Proposition», and the Business Model, «Business Model Canvas».

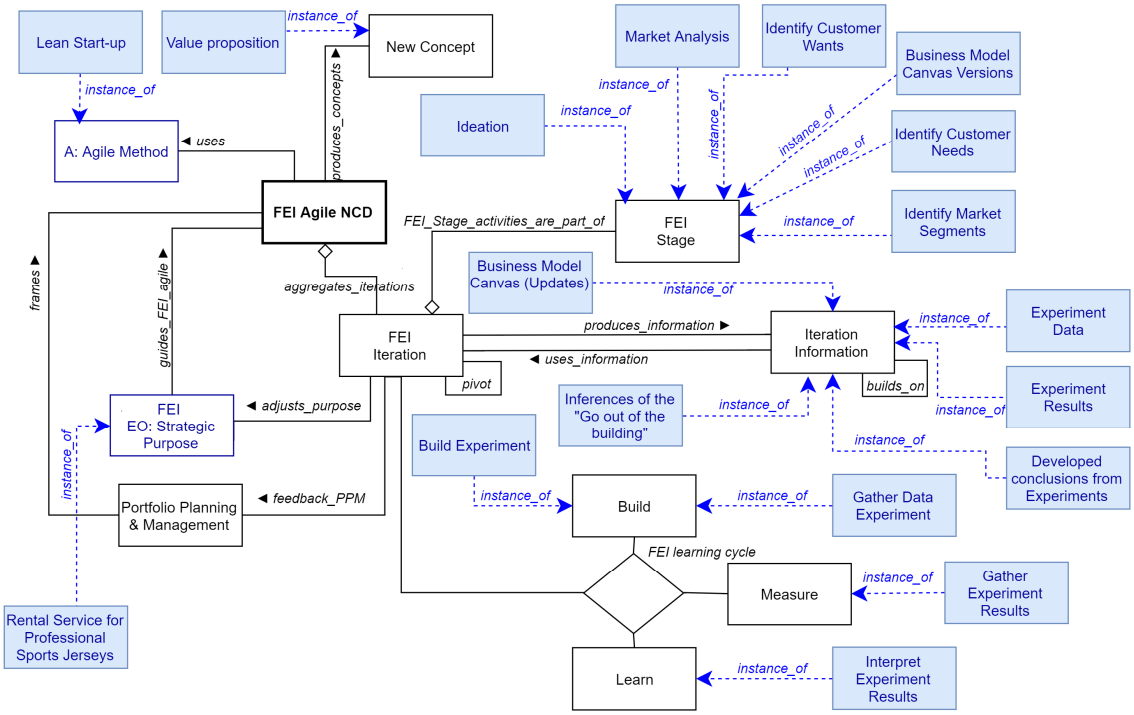

Figure 6-3 Instantiation of the Agile NCD Sub-ontology in the context of the Jersey Square case

The principles of the Lean Start-up process, that stem from software development agile methodologies, are in fact embedded in the FEI^{2}O. The application case demonstrated how the process is mapped into the ontology. As a result, this ontology provides the theoretical framework on which the Lean Start-up process may be anchored. This perspective into the Lean Start-up process helps demonstrating how it may be used in the context of established companies that aim to have a more agile FEI process. This is fostered by the FEI^{2}O proposed the connection between the Agile NCD Sub-Ontology and the sub-ontology Portfolio Planning & Management. These further concepts were not instantiated due to the nature of the application case.

These instantions depicted the following FEI^{2}O characteristics: a) a holistic representation of the FEI; b) a management perspective contemplating an iterative nature to the development of FEI Activities; c) a flexible approach to adjustment and fine tuning of the on-going FEI process; and, d) an encompassing model that welcomes other methodologies and tools.

6.3.2 mobLee Case

mobLee is the largest Latin American mobile platform for events, according to the Company Chief Technology Officer (CTO), one of its partners. Considering the Brazilian Regulation, mobLee is a public limited company. They recently reached a total of 40 employees. The business started in 2011, and, until now, the company has already developed and launched 510 apps. Their products essentially solve the client's pains, combining features of the digital and physical world, therefore, creating effective connections between people, companies and products in events. mobLee is an established company in Brazil run by five partners, two are representative of technology, two partners came from the event market field and one is an investment fund. The following paragraphs describe the instantiation of the FEI^{2}O in this company.

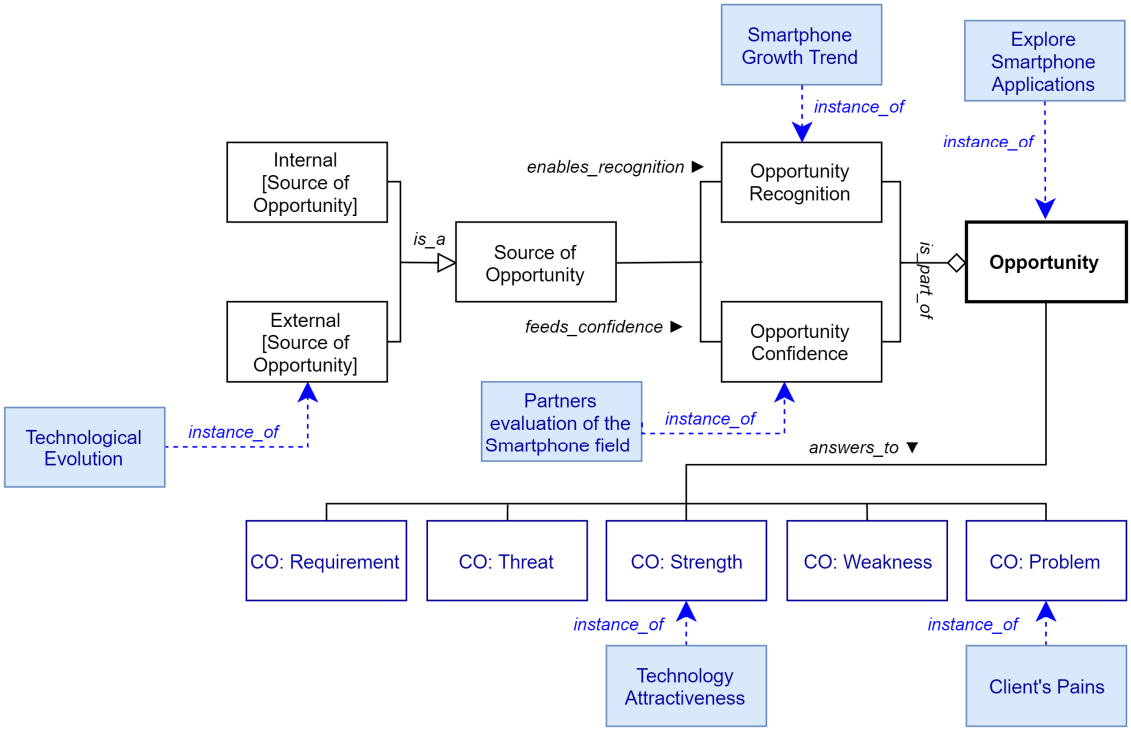

Figure 6-4 Partial Instantiation of the Sub-ontology FEI Purpose *focused on* Opportunity, mobLee Case

Figure 6-4 illustrates the very beginning of the FEI Purpose sub-ontology. The «Technological Evolution» of Smartphones was (and it still is) envisioned by the mobLee as a SOURCE OF

OPPORTUNITY. At the beginning of the business the «Partners evaluation of the Smartphone field» instance of the OPPORTUNITY CONFIDENCE helped them to identify the OPPORTUNITY «Explore Smartphone Applications». Their first client was an Event Organiser; hence, their OPPORTUNITY was a response to solve their «Client's Pain». The «Technology Attractiveness» of the solution provided by the mobLee is an instance of the Strength. Currently, this is also true as the development of new products still consist of answers to the «client's Pains» instances of CO: PROBLEM.

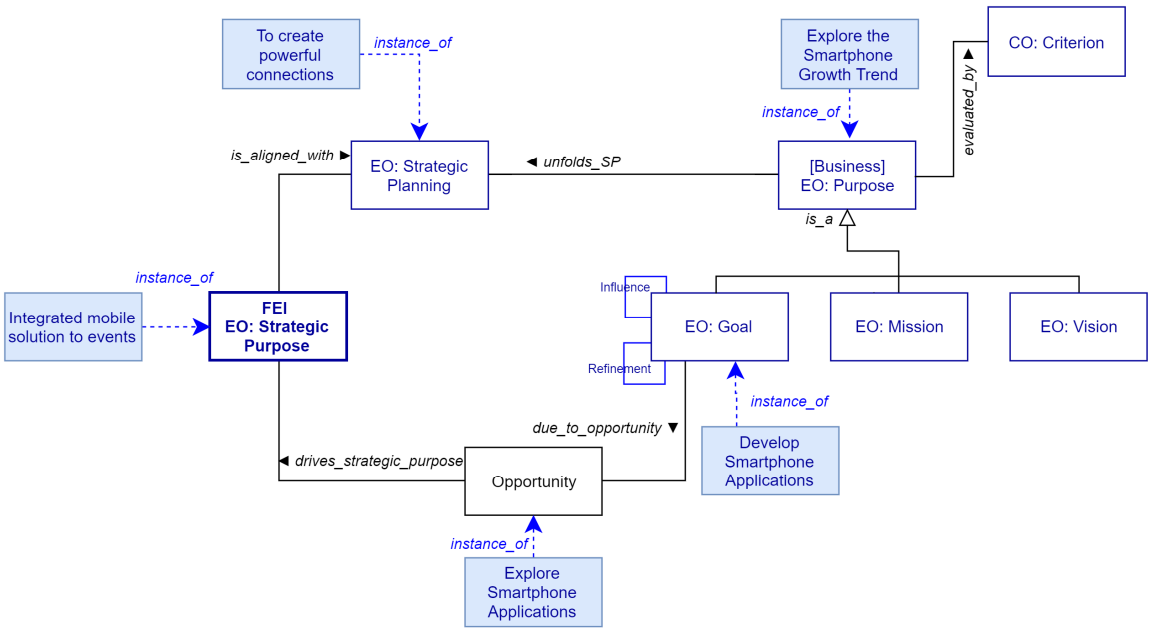

Figure 6-5 Instantiation of the Sub-ontology FEI Purpose, mobLee Case

Figure 6-5 illustrates the instantiation considering the complete representation of the Sub-ontology FEI Purpose. The mobLee first client helped to define that the company would offer «Integrated mobile solution to events» an instance of the FEI EO: STRATEGIC PURPOSE. Currently, this is still representative. This instance was driven by the OPPORTUNITY instantiated by the aim to «Explore Smartphone Applications». Due to the identified OPPORTUNITY, an EO: GOAL was defined «Develop Smartphone Applications». Therefore,

the mobLee [Business] EO: PURPOSE is instantiated by the aim to «Explore the Smartphone Growth Trend» that unfolds into the EO: STRATEGIC PLANNING, instantiated by «To create powerful connections» between people, companies and products in events. The Strategic Planning and the Portfolio Planning & Management are vital concepts of the Sub-Ontology Portfolio Planning & Management. Figure 6-6 illustrates its instantiation considering the mobLee case.

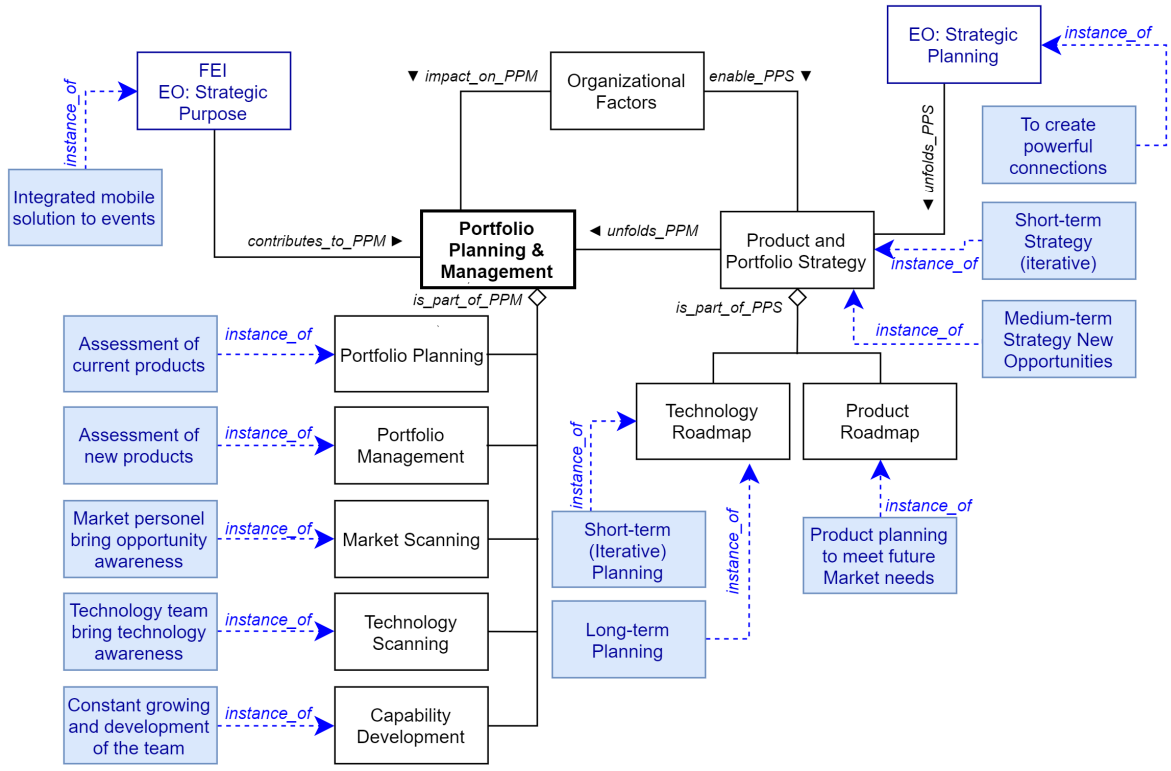

Figure 6-6 Instantiation of the Sub-ontology FEI Portfolio Planning & Management, mobLee Case

The mobLee FEI Purpose is to offer integrated mobile solutions to events and it is aligned with their Portfolio Planning & Management (PP&M). mobLee PP&M has a dynamic configuration considering active projects and potential new developments. It comprises «Assessment of current products», «Assessment of new products», «Market personnel bringing opportunity awareness», «Technology team bringing technology awareness», and «Constant growing and development of the team». These instances relate to PORTFOLIO PLANNING, PORTOFOLIO MANAGEMENT, MARKET SCANNING, TECHNOLOGY SCANNING

AND CAPABILITY DEVELOPMENT, respectively. They are components of the PP&M that is unfolded by the PRODUCT & PORTFOLIO STRATEGY, which have as instances «Short-term Strategy» and «Medium-term Strategy New Opportunities». The first addresses a follow-up of the current products exploring its potentialities and the Medium-term Strategy regards definitions for exploring new opportunities in a medium-time horizon. For doing so, the mobLee makes use of «Product Planning to meet future needs», an instance of the PRODUCT ROADMAP; and in terms of TECHNOLOGY ROADMAPPING the company uses «Short-term Iterative Planning» and «Long Term Planning».

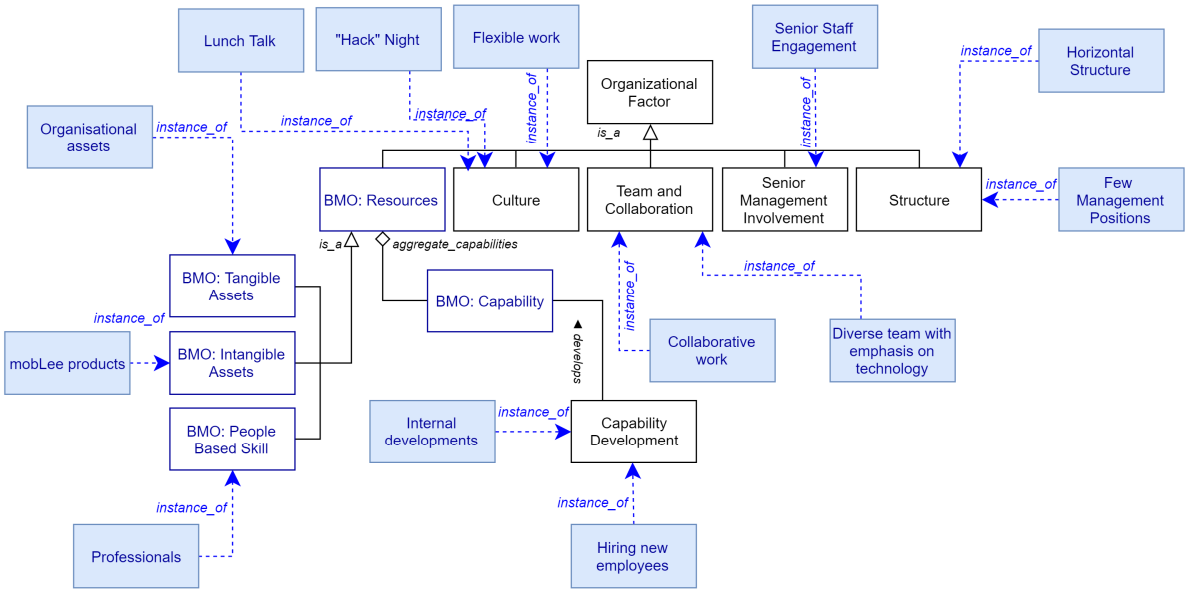

Figure 6-7 Instantiation of the Sub-ontology FEI PP&M *focus on* Organisational Factor, mobLee Case

Figure 6-7 illustrates mobLee Organisational Factors, a component of the Sub-ontology PP&M. Organisational factors support the development of opportunities and technologies by impacting on the PP&M and enabling the P&PS. Therefore, they play a vital role in the Front End of Innovation. mobLee Organisational Factors encompasses its rapidly growing business. The company has a «Horizontal Structure» with «Few Management Positions», both are instances of STRUCUTURE. The «Senior Staff Engagement» represents the engagement of senior positions in projects and processes. Furthermore, according to the CTO, the work is

developed by the mobLee team in a collaborative environment. mobLee has a variety of professionals with diverse backgrounds, due to the core business with emphasis on technology specialists. Hence, the «Diverse team with emphasis on technology» performs the «Collaborative work», they represent instances of TEAM AND COLLABORATION.

Recently, mobLee released the statement of their culture code in their blog[7]. The company has «Flexible work» an instance of CULTURE, hence there are flexible working hours for the employees. Other instances of mobLee culture are the «Hack Night» and «Lunch Talk» events to gather the engagement of the team in exploring ideas and opportunities.

The resources emphasised by one of the partners relates to «Organisational assets», «mobLee products» and «Professionals» instances of BMO: TANGIBLE ASSETS, BMO: INTANGIBLE ASSETS and BMO: PEOPLE BASED SKILLS, respectively. Lastly, in terms of CAPABILITY DEVELOPMENT, mobLee focus on «Internal Developments» and «Hiring new employees».

Figure 6-8 shows the mobLee dynamic process of developing a new concept. The company uses «Scrum» as an A: AGILE METHOD. The dynamic development is enabled by the «Design Sprint», an instance of the FEI AGILE NCD. This is an iterative methodology that gather «Gather Clients Data», «Gather and Analyse Clients Data» and «Interpret Clients Data» in a period of few days, they are instances of BUILD, MEASURE and LEARN. The «Minimum Viable Product» is the prototype, which is tested and analysed according to the market response. At times, this dynamic process unveils new opportunities and this is feedback to the PP&M, hence the «Consciousness about new opportunities» is an instance of the PP&M.

[7] https://www.moblee.com.br/blog/2017/08/definindo-cultura-empresa-que-se-prepara-para-escalar/

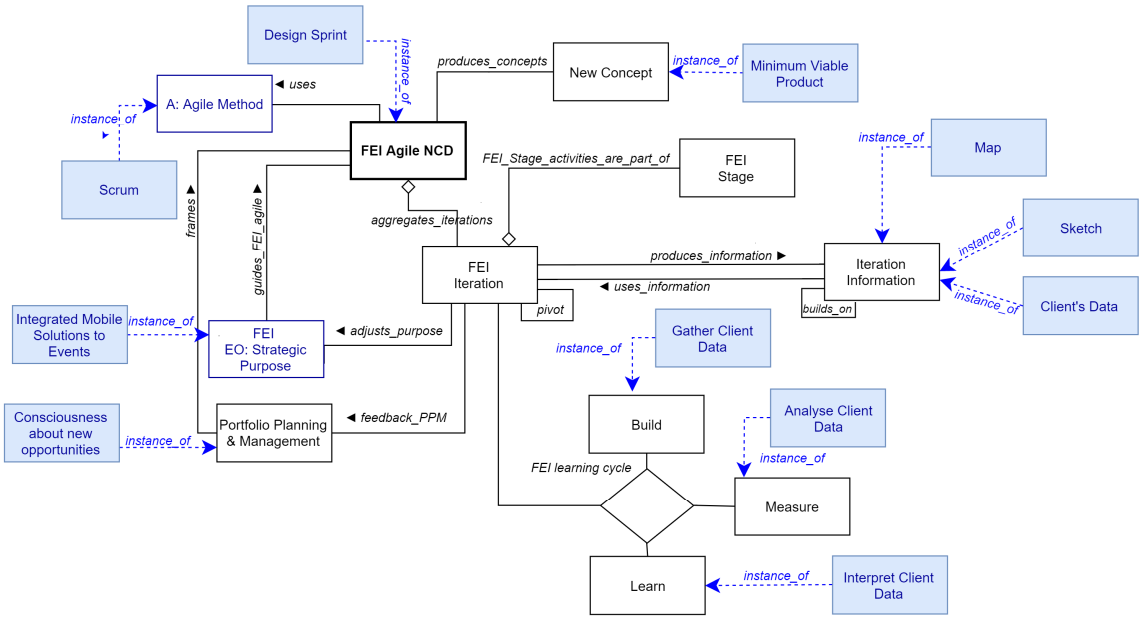

Figure 6-8 Instantiation of the Sub-ontology FEI Agile NCD, mobLee Case

Figure 6-9 illustrates the variety of activities applied to the development of a new concept.

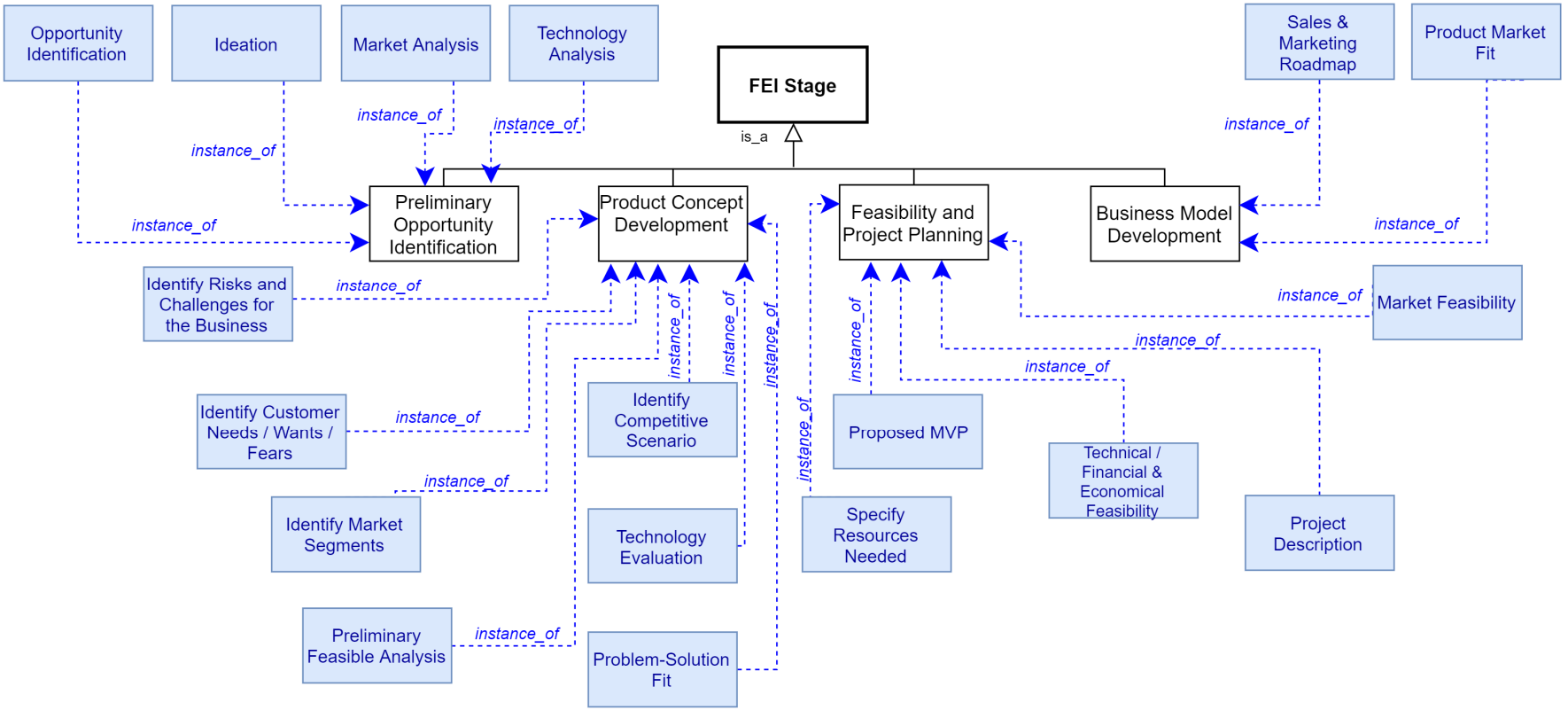

Figure 6-9 Instantiation of the Sub-ontology FEI Stage, mobLee Case

The company makes use of an Agile New Concept Development, depicted in Figure 6-8. They use information from clients', market and technology, considering Agile Principles BUILD, MEASURE and LEARN. The activities that mobLee uses for achieving what they call Minimum Viable Product consist of the PRELIMINARY OPPORTUNITY IDENTIFICATION; PRODUCT CONCEPT DEVELOPMENT; FEASIBILITY AND PROJECT PLANNING and BUSINESS MODEL DEVELOPMENT. The latter refers to the necessary adjustment of the firm to new products. The instances, in Figure 6-9, represented their reality of work concerning types of activities demanded for the concept development.

In the project phase, the iterations occur with mobLee Clients and when the product is launched the iterations consist of feedback mainly from the users. Concerning the «Identification of Wants/Fears/Needs», the company focus on the needs, as they try to understand the underneath motivation of the client, in order to provide effective solutions. This means that the solution provided may not be the envisioned by the client, but a product consistent with the technology feasibility. Hence, the "needs" is the driver and is complemented by the "wants". Moreover, the «Project description» consists of a summarised and objective document, with the information of the «Specify resources needed». Lastly, some activities are used to feed not only FEI Projects but also the PP&M, for instance «Market Analysis» and «Technology Analysis».

According to the CTO at the beginning of the business development none of the partners had formal knowledge of the concepts comprised by the beginning of the innovation process, for instance they did not have portfolio planning & management; they were not addressing marketing issues; the staff was technology oriented; and, for the CTO, a tool like the FEI^{2}O would have been of valuable assistance. In accordance to this, it is important to highlight two important applications that stemmed from the ontology evaluation process:

- A call for a Methodological Roadmap, for entrepreneurs and enterprises, to guide them in the FEI process. Further research addressing a consistent number of instantiations would benefit the theorise and justify (components of the DS) to address issues related to the FEI^{2}O based tools and their performance.
- The generation of Guidelines and an Audit Tool offering a guide of the expected milestones to be achieved throughout the FEI process.

The FEI management perspectives benefits are well established by (Boeddrich, 2004; Chang, Chen, & Wey, 2007; Cooper & Edgett, 2012; Khurana & Rosenthal, 1997). For instance, Giles & Cormican (2014) synthesised the literature to identify four critical success factors (CSFs) known to be effective in the successful management of the FEI process. FEI^{2}O is likely to be an enabler of effective FEI management. Table 6-5 presents an analysis to assess the compliance of the FEI^{2}O with these CSFs for FEI effective management.

Table 6-5 CSF for FEI effective management adapted from Giles & Cormican (2014) *vs* FEI^{2}O

Concept	**Supporting authors**	**FEI Integrative Ontology**
Strategy	(Cooper, 2000; Khurana & Rosenthal, 1997; Langerak et al., 2004; Martinsuo & Poskela, 2011)	The strategy is addressed by the following concepts: - EO: BUSINESS PURPOSE - FEI: STRATEGIC PURPOSE - EO: MISSION - EO: VISION - EO: GOAL o EO: STRATEGIC GOAL - PRODUCT & PORTFOLIO STRATEGY

Resources	(Khurana & Rosenthal, 1997; Koen et al., 2002, 2014a, 2014b; Osterwalder, 2004)
	(Koen et al, Osterwalder, Khurana and Rosenthal)
		The resource is addressed by the following concepts:
		- BMO: RESOURCES
		  o BMO: TANGIBLE ASSETS
		  o BMO: INTANGIBLE ASSETS
		  o BMO: PEOPLE BASED SKILLS
		- BMO: CAPABILITY
		- CAPABILITY DEVELOPMENT

Process	(Boeddrich, 2004; Cooper, 2000; Markham, 2013)	The process is addressed by the following concepts: - FEI AGILE NCD - Alignment Process of PP&M and P&PS - FEI EO: STRATEGIC PURPOSE process development
Climate/ Leadership	(Khurana & Rosenthal, 1997; P. A. Koen, Bertels, Klein et al., 2014)	Climate / Leadership is addressed by the following concepts: - ORGANISATIONAL FACTORS - FEI ACTORS o CO: ORGANISATIONAL ROLE

This cross-analysis of the findings of Giles & Cormican (2014) and the FEI^{2}O demonstrates that the FEI Integrative Ontology covers critical success factors (CSFs) recognized as effective

factors for a successful management of the FEI. Moreover, the mobLee instantiation case illustrated the application of the FEI^{2}O in a context of a established company, and the company CTO recognised the merits of the approach.

6.4 Other Applications

The following sections introduce the envisioned applications of the FEI^{2}O Canvas and its possible benefits in an educational context.

6.4.1 Applications in Entrepreneurship Education[8]

Entrepreneurship is a key component for answering the need for creating and strengthening businesses. The expected results of entrepreneurial activities are the creation of jobs and innovative firms. Therefore, entrepreneurship education plays a vital role in engaging students in the systematic practice of innovation. An entrepreneur committed to a management role has a significant perspective to innovation and entrepreneurship endeavour, both tasks demanding a management practice for creating change. In this context, the Front End of Innovation (FEI) plays a critical role. However, this is a challenging phase for entrepreneurs and companies as the FEI demands a variety of activities and approaches, necessary to overcoming the risks entailed in a new concept development, which hopefully will be unfolded as a new product or service, or even a business.

It was not only until recently that universities began to pay attention to this vital and uncertain phase of the innovation process, the Front End of Innovation in an entrepreneurial context (Jaskari, 2015). The process of how to manage the FEI in its entirety, from the identification of an opportunity until the achievement of a new concept development is not always clear for the entrepreneur. One of the causes for this difficulty is the lack of understanding of the beginning of the innovation process, the FEI. Moreover, regarding management skills, other difficulties may arise from the need to consider the size of the company, the decision-making

[8] This section presents in a great deal the content of the paper "The Front End of Innovation (FEI) in the context of Entrepreneurship Education" presented in the Conference on Entrepreneurship Education (CEE'2017), Aveiro, Portugal.

style, the organizational culture and frequency of new products introduction, to choose a front-end solution (Khurana and Rosenthal, 1997).

Graduate teaching in New Product Development is a widespread discipline taught in universities (Martinsuo, 2009). However, the early phase of innovation has just begun to receive attention. One critical question raised by this author was “How should the challenging tasks of managing the early phase of innovation be taught in a university context?” (Martinsuo, 2009, p. 147). Answers to entrepreneurship education have been considering the need for both entrepreneurial and managerial competencies, considering of special importance managerial competencies as the business grows and to support successful business growth (Mitchelmore & Rowley, 2010).

In this context, to understand how these entrepreneurial skills relate to the skills needed to support the Front End of Innovation is an added value structure to FEI courses and curriculum in a university context or even for in-company developments. To this end, the National Content Standards for Entrepreneurship Education (NCSEE) Toolkit (http://www.entre-ed.org/Standards_Toolkit/) may be a starting point for a cross-analysis. This toolkit was designed to provide the tools necessary for developing curriculum for entrepreneurship programs. It is, therefore, a valuable platform for discussing the toolkit relation with FEI activities. The expected results are: a) Widening educators’ perspectives in the process of curricula preparation in Entrepreneurship; as well as b) enhancing students FEI competences.

The FEI^{2}O concepts will be mapped and further analyzed, whenever possible, into the Entrepreneurship Education National Content Standards (NCSEE) skill list. As a result, it is expected to understand the manner by which these two conceptual frameworks map into each other, and to assess how each model can build value by bringing both together. The NCSEE comprises fifteen major standards organized into three sections:

- Entrepreneurial Skills,
- Ready Skills, and
- Business Functions.

The Entrepreneurial Skills is a key section and its influence is projected into the Ready Skills and Business Functions. It comprises, for instance, the processes and traits/behaviors related to new and stablished ventures, and the activities related to create, to drive and to change – new: markets, products, businesses. Therefore, due to its key role and FEI representativeness, the Entrepreneurial Skills section was subject to an exploratory comparative analysis with the FEI^{2}O, focused on one of its subsets, the "Entrepreneurial Process".

Table 6-6 shows a preliminary analysis of concepts and processes related to the entrepreneurial process and their relations with the building blocks of the FEI Ontology.

Table 6-6 Preliminary analysis of NCSEE Toolkit *versus* FEI Ontology

Discovery		
A.01	Explain the need for entrepreneurial discovery	OPPORTUNITY FEI EO: STRATEGIC PURPOSE [BUSINESS] EO: PURPOSE PP&M FEI STAGE Activities FEI AGILE NCD
A.02	Discuss entrepreneurial discovery processes	
A.03	Assess global trends and opportunities	
A.04	Determine opportunities for venture creation	
A.05	Assess opportunities for venture creation	
A.06	Describe idea-generation methods	
A.07	Generate venture ideas	
Concept Development		
A.09	Describe entrepreneurial planning considerations	FEI STAGE PP&M
A.15	Describe strategies to protect intellectual property	N/A
Resourcing		
A.17	Distinguish between debt and equity financing for venture creation	FEASIBILITY AND PROJECT PLANNING **is_a** FEI STAGE
A.21	Describe considerations in selecting capital resources	
Actualization		
A.30	Develop and/or provide product/service	FEI AGILE NCD FEI STAGE
A.31	Use creativity in business activities/decisions	ORGANISATIONAL FACTORS RESOURCES PEOPLE BASED SKILLS FEI ACTORS
A.25	Explain the complexity of business operations	BUSINESS MODEL DEVELOPMENT **is_a** FEI STAGE
A.27	Explain the need for business systems and procedures	

A.28	Describe the use of operating procedures	
Harvesting		
A.35	Explain the need for continuation planning	PP&M alignment with P&PS

The exploratory comparative analysis, presented in Table 6-6 Preliminary analysis of NCSEE Toolkit *versus* FEI Ontology illustrates how the FEI^{2}O covers the "Entrepreneurial Process" as a skill set defined by the NCSEE. The analysis of this table indicates the evident relationship between a subset of required skills for entrepreneurship education and the concepts handled at the FEI. Another finding, concerns the indication that an in-depth understanding of the FEI ontology may help entrepreneurship educators to enrich those skills, identified for entrepreneurship education, by reaching to an organized body of knowledge that will support an in-depth understanding of the process.

Figure 6-10 provides a high-level demonstration of the FEI process, it highlights the role of the actor (entrepreneurs, entrepreneurial team and possible stakeholders - e.g.: investors) and their engagement in the process of new concept development. The figure further frames this process in a Strategic Purpose and Portfolio Planning & Management (PP&M), regardless of their formal existence, as it happens in a company. In fact, the entrepreneur may not have these as formally established documents, but these concepts will likely be in his/her mind along the entire process. The iterative nature of the process also emerges from the ontology, thus making it explicit for the student the nature of the process.

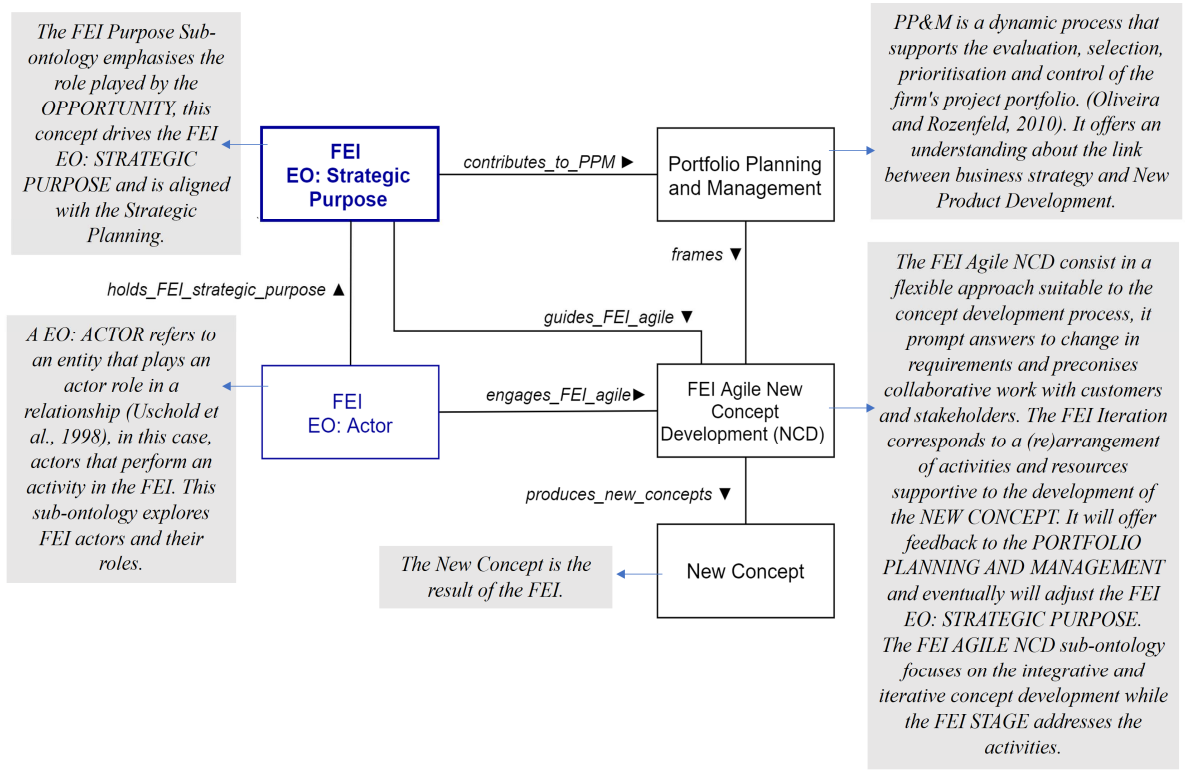

Figure 6-10 The High-Level Ontology with descriptions

In this representation, the FEI EO: STRATEGIC PURPOSE contributes to the PORTFOLIO PLANNING & MANAGEMENT (PP&M). In its turn, the PPM frames the FEI AGILE NEW CONCEPT DEVELOPMENT (NCD) while the FEI EO: ACTORS are engaged in the FEI AGILE NCD to produce the NEW CONCEPT. The FEI AGILE NCD comprises a combination of iterations. These iterations consist of a configuration of activities integrated in the so-called FEI Stages. This process continues as long as necessary to achieve a NEW CONCEPT.

The FEI activities carry a dynamic and iterative flow among them enabled by the FEI ITERATION (BUILD/MEASURE/LEARN loop – part of the FEI Agile NCD). In this process, for each interaction and inside each FEI STAGE, tools and supporting methodologies will be used as adequate. Given the encompassing nature of the FEI^{2}O to frame supporting methodologies, this conceptual model may be helpful in the realm of entrepreneurship education as it could provide a perspective of which methodologies to apply to each of the FEI Stage and, as a comprehensive and integrative approach to the entire FEI process. Overall, the adoption of the FEI^{2}O as a reference framework for entrepreneurship education, specifically

associated to the identified NCSEE skills, will likely bring value in the organisation of the entire conceptual framework, and better guide students in navigating the entrepreneurial process.

6.4.2 The Model as a Base for FEI Future Research

At the best of the researchers knowledge, there is no integrative ontology covering the entire FEI process. However, some works pay considerable attention to individual sections. For instance, two works concerning the ideation:

- "Innovation and Ontologies: Structuring the Early Stages of Innovation Management" by Bullinger (2008). This research develops an ontology aimed at increasing the effectiveness of management of the idea assessment and selection in the FEI for a technology-based-incremental product innovation.
- "An Idea Ontology for Innovation Management" (Riedl et al., 2009). This ontology offers a common language to promote interoperability between tools and to help the ideation. The benefits envisioned for this work were semantic reasoning and automatic analysis. It was intended that the ontology captured a core idea concept and further concepts to support collaborative idea development.

Besides these FEI works, more examples of ontologies[9] in an innovation context are related to:

- Knowledge management (Batzias and Siontorou, 2012; Harmaakorpi and Mutanen, 2008; Li et al., 2015; Trappey et al., 2013; Gardner, 2005; Barradas, 2015).
- User-driven innovation (Christiansson et al., 2008).
- Creativity in the process of designing for innovation (Gero and Kannengiesser, 2007).
- Innovation processes (Scozzi, Garavelli and Crowston, 2005; Jurczyk-Bunkowska and Paweloszek, 2015; Spyns et al., 2004).
- Solving technical conflict (Jiang et al., 2008).

[9] The searches were set up using the pair of words: "innovation" AND "ontology" in august/2015. The proximity operator: AND was used, it was not applied any restriction refinements, other than "only article. The results related with ontology approaches in context of innovations are showed above grouped in categories. It was taken into consideration the title and/or abstract to provide the means to classify the content of the works.

- Project management (Bullinger et al, 2005).

A more comprehensive and critical work consists of the study by Lippmann (2013). This author emphasises the need for innovation-related knowledge engineering by defending a unification of a core ontology for innovations.

Thus far, no comprehensive approach covering the entire FEI has been proposed. This original work offers a comprehensive representation of concepts, relations, organisational factors, resources, activities, processes and roles of the Front End of Innovation. This contribution provides a consistent ground for future research in the FEI. Moreover, this addition to the knowledge base provides a common language for FEI concepts. Therefore, it may minimise conflicts concerning concepts definitions, for instance the misuse of idea and opportunity as interchangeable concepts.

6.5 Generalisation

This work is a practical applied research supported by the Design Science Research Paradigm. The FEI phenomena was analysed considering the Knowledge Base and the Environment (Hevner et al. 2004), as the research considered the FEI literature and reuse of other ontologies as well as the artefact elicitation with domain experts. Therefore, integrating different perspectives to help build and evaluate the artefact. These developments provided evidence to claim the generalisation of the work.

The results of this research belong to the field of the Front End of Innovation. The produced artefact (FEI^2O) is suitable for different contexts of applications, e.g.: educational, business and research contexts. These scenarios, share the same knowledge base, the FEI Integrative Ontology, but with different operating environments, problems and types of users. Therefore, positively impacting the validation of this research in different contexts.

6.6 Conclusions

This chapter evidenced the shortcomings in the main FEI Reference Models when compared with the FEI Integrative Ontology, which bridges across these models and fills in their gaps. The proposed FEI^{2}O implemented and modelled FEI concepts that arose from the knowledge base and the environment. The basis on which the ontology was built enabled the participation and contribution of several FEI actors, provisioning the model with different insights from the practice.

The FEI Integrative Ontology is a comprehensive artefact and it unfolds in a variety of applications, some already illustrated. The FEI^{2}O has some envisioned benefits, namely:

- It allows the systematisation of the efforts applied to the beginning of the innovation process;
- It helps to provide a vision for the definition of an FEI Purpose, an important attribute to produce engagement among the actors involved;
- It provides an orientation towards the efforts applied in the opportunity screening as well as a basis (FEI activities) for analysing the FEI Purpose;
- It offers a foundation that aims at providing greater assertiveness in developing a new concept;
    - A successful NCD may eventually lead to the unfolding of a new business;
- It supports the definition of the strategic purpose of the FEI;
- It aligns the strategic purpose of the FEI with the business purpose of the company;
- It enables an Agile development of a New Concept;
- It preconises the use of criteria for the resources allocations;
- It mobilises organisational resources to implement Portfolio Planning;
- It recognises the organisational factors critical to the execution of the business strategy;
- The model highlights existing organisational resources and capabilities as well as acknowledges the need to develop new capabilities and, if necessary, partnerships;
- It guides the FEI dynamic by iterating and adjusting the purpose of the FEI and offering feedback to the Portfolio Planning & Management; and,

- It recognises the various actors and their roles in the activities of the beginning of the innovation process.

The artefact offers a comprehensive and integrative approach of the FEI benefiting FEI literature, business and educational contexts. Further developments of the by-products of this work also have the potential to promote beneficial aid to this phase of the innovation process, (see Section 1.6 p. 32).

The building blocks of the ontology answer the demands of effective management practices at the Front End of Innovation (FEI) process, as the FEI^2O

- Gives effective attention to FEI activities, as they represent greatest differentials for success (Giles & Cormican, 2014).
- Provides a comprehensive and integrative knowledge representation enabling a management approach to enhance FEI effectiveness, as this phase is considered the greatest weakness in the innovation process (Khurana & Rosenthal, 1997; Koen et al., 2002).

The work fulfilled research suggestions, namely the need for developing an ontological approach to the adjoining disciplines of R&D and technology management (Bullinger, 2008); and the need for research about Preliminary Technology Assessment and Early and Well-Defined Product Definition for the FEI (Eliens and Xavier, 2015).

This work represents an addition to the FEI domain, relevant to entrepreneurs, innovation managers, strategic managers, general management academics, companies with an R&D department, universities and Technology Transfer Office. The applications' case used for instantiating the FEI Integrative Ontology demonstrated both the utility and feasibility of the model in two different contexts. The instantions, Jersey Square and MobLee case, depicted the following FEI^2O characteristics: a) a holistic representation of the FEI; b) a management perspective contemplating an iterative nature to the development of FEI Activities; c) a flexible approach to adjustment and fine tuning of the on-going FEI process; and, d) an encompassing model that is able to frame existing methodologies for the FEI.

Chapter 7 Conclusions

7.1 Summary and Final Considerations

The Front End of Innovation is a recent domain of study in the New Product Development literature. Nonetheless, this field has encompassed a wide variety of approaches trying to cope with its peculiar multidisciplinary nature. For instance, the opportunity concept highlights the multitude of approaches that FEIs activities have:

- Koen et al., (2002) address this concept proposing Opportunity Identification and Opportunity Analysis activities;
- Cooper (2001, 2008) argues for opportunity issues as part of the ideation. Therefore, the opportunity is addressed in the scoping idea phase of the Stage-Gate Process;
- Khurana and Rosenthal (1997, 1998) deal with opportunity in the so-called pre-phase zero. For these authors, the opportunity demands a clear understanding of the existing business and technology plans. It is responsible for coping with product & portfolio strategy; And,
- Reid and De Brentani (2004) and De Brentani and Reid (2012) address the opportunity activities throughout the Boundary Interface, Gatekeeping Interface and Information Flows of their model.

The FEI also presents some managerial challenges for scholars and practitioners due to its variety of activities and decisions. For instance, entrepreneurs are faced with issues as how to understand the opportunity context; how to generate, enrich and select ideas; and, how to develop a new concept that will be successful in the market. Although there is an evident fuzziness at the beginning of the innovation process, it is well documented that the FEI may benefit from a managerial point of view. Specially one that is suitable for the FEI nature. A comprehensive and integrative knowledge representation may come in aid to this context.

At the beginning of this work, it was identified that the FEI had received greater attention in recent years both regarding depth and number of publications. Even though several vital contributions have been made so far, there was room for improvements on holistic perspectives to the FEI knowledge domain.

This objective consisted in proposing a comprehensive and integrative model organising the body of knowledge around the FEI, making it useful as an effective basis for future steps towards organising and managing the FEI processes. The challenge was expressed by the following research questions:

1) How can we build a comprehensive knowledge representation of the Front End of Innovation?
   a) Which components would this FEI knowledge representation comprise?
   b) Which would be the boundaries of this knowledge representation?

One of the benefits of ontologies is to represent knowledge with an effective modelling potential. This characteristic is fundamental to model the dynamic and even "fuzzy" nature of the FEI. A vital strategy for companies in terms of managing the Front End of Innovation is to design its own front-end of innovation processes, by considering the nature of its business. The FEI^{2}O could be their starting point to adapt their own solution. The use of ontologies is not restricted to the realm of Artificial Intelligence, there are emerging ontologies in educational as well as in corporate contexts.

The overarching thesis contribution is found in the developed artefact, the Front End of Innovation Integrative Ontology. The FEI^{2}O enhances the understanding and translates the variety of activities, processes and responsibilities in the FEI promoting a comprehensive and integrative knowledge representation. Moreover, it provides a foundation useful for contributing to FEI future research.

The FEI^{2}O covers concepts such as: purposes, roles, processes, activities, strategy and portfolio planning, facilities and actors situated all along the FEI process, from the opportunity discovery until the concept definition. The ontology implemented 98 concepts throughout the six sub-ontologies. This model supports the decision of which opportunities, ideas and concepts are

worth to developed by addressing organisational, technological and market issues. Moreover, the FEI^{2}O provides the framework to bring in supporting tools and methodologies in order to develop FEI Activities.

The FEI^{2}O comprises critical FEI domains, concepts and their relations, which are represented by the FEI high-level sub-ontology; FEI Purpose sub-ontology; FEI Portfolio Planning & Management; FEI Agile NCD; FEI Stage and FEI actors. The FEI high-level sub-ontology represents the key relationships of the key concepts. These sub-ontologies answered the Competence Questions and they represent the boundaries of the FEI^{2}O, starting from the source of an opportunity until the achievement of a new concept.

The FEI Integrative Ontology may unfold several by-products, for instance: a comprehensive tool and supporting methodology to address the FEI by means of a FEI^{2}O Canvas; or, a novel approach to look at Entrepreneurship Education.

7.2 Thesis Contributions

The contribution of the FEI Integrative Ontology is to offer a comprehensive and integrative knowledge representation of the FEI. Considering the gaps of the main FEI Reference Models, this work can fill in the need of a holistic perspective with an iterative nature suitable for the FEI. A special emphasis must be given to the FEI^{2}O characteristics: a) a holistic view of the FEI; b) the enabling of a management perspective contemplating an iterative nature of FEI Activities; c) flexibility to adjustment and fine tuning of the FEI processes; and, d) a model that supports and frames the use of any methodologies and tools to assist in the FEI activities.

In what concerns the FEI, there is relatively little research that studies the management of this phase in the innovation process (Robins and O'Gorman, 2015). Hence, the thesis contributes to this knowledge domain by providing a comprehensive and integrative approach, a domain model. The FEI^{2}O is a domain model as it explicitly provides a description of a domain regarding: concepts, properties and relations of concepts. Moreover, it defines a common vocabulary and a shared understanding.

7.3 Research limitations

There are always viable alternatives to develop an ontology, once the ontology design can be understood as a creative process (Cristani & Cuel, 2005; Noy & McGuinness, 2001). This work followed the methodology suggested by Noy & McGuiness (2001), the Ontology Development 101.

The ontology does not display cardinalities in order to provide flexibility of relations. Cardinality is a notation that indicates how often a given relation can be set (a relation may be used any number of times or not be used).

The development of the ontology sets the limitation of this work as it answers the research problem. Additional studies are suggested concerning the developments and evaluation of the by-products of the FEI^{2}O. These secondary results prove to be very laborious to develop and are not covered by this thesis. In sum, the aim of the work does not included the test and evaluation of the by-products by means of study cases (e.g. FEI^{2}O Canvas), however, the adequability of the model was analysed via evaluation phase and the utility of the model was tested via instantiation.

The Research Activities (March & Smith, 1995) focused on Build and Measure while the Theorise and Justify received less empahsis, similarly to other design science theses (Osterwalder, 2004; Bullinger, 2008; Barradas, 2015).

The by-products of the FEI^{2}O, for instance, the FEI^{2}O Canvas is only preliminary identified and not explored in this thesis, except for the propositions of further research.

The instantiations are basic demonstrations of the applicability of the model and represent a limitation of the work with only two cases. Section 7.5 (p. 185) suggests further research considering a varied business fields and geographic location to explore FEI^{2}O based tools and their performance and consequently to address the theorise and justify (Design Science Research Framework - March and Smith, 1995).

The evaluation procedures are limited to the number of interviews and number of participants in the Focus Groups as well as to the domain experts background. These experts are

researchers, professors, entrepreneurs, innovation managers, professionals from venture capital companies and technology transfer office. Therefore, the data saturation concerns the evaluation procedures in this setting.

7.4 Recommendation for Managers

The FEI^{2}O offers a comprehensive and integrative knowledge representation of the beginning of the innovation process. Its design embodies the ontology power modelling to represent concepts and their relations. This feature enabled a holistic representation with an iterative nature compatible with the FEI characteristics. The artefact developed has several benefits for managers:

- It represents a set of steps organised according to key FEI drivers; this may unfold management guidelines for FEI processes;
- It provides a vision of the FEI process; therefore, helpful to guide the resources allocation, the decision-making process and other managerial decisions;
- The FEI^{2}O holds the potential to help managers to broad their focus from *doing things right* (efficiency) to *doing the right things* (effectiveness); helping them to minimize costs and increase value of developed concepts.
- The in-depth and broad coverage of the FEI^{2}O allow managers to customise their front-end solutions considering the size and field of activity of the company, business purpose, the organisational factors, strategy, and the portfolio planning.

7.5 Directions for Future Research

The present work unfolds some issues that need to be explored, therefore they are defined as potential avenue for further research. For instance, the need to address:

- The role and significance of customer orientation in the FEI Iteration.
- An audit tool that unfolds the tasks assignment for each FEI actor considering different FEI roles.

- An ontology for formalizing the R&D contribution to the FEI, considering R&D as anticipation of technological developments.
- Further studies on instantiations, in different fields of activity and even geographically, which represent new contributions, in order to theorise and justify the FEI^{2}O, by addressing issues related to FEI^{2}O features and their performance.
- An ontology is a machine reading model, it is suggested to implement the FEI^{2}O into a computer-based tool. Further potential of the ontology lies in its extension into an analytical tool, for example, for designing, simulating and comparing FEI solutions.
- A promising research reflects the use of the FEI^{2}O as a matrix to analyse the existence of patterns characterizing successful FEI solutions, as well as constraints.
- Further developments to analyse and to balance the level of influence of FEI activities for the concept development (Kleinschmidt, de Brentani and Salomo, 2007).

At last, another potential subject for future research concerns the circular economy, in this case how it would be an interplay of the FEI Integrative Ontology and Sustainable Innovation. Firms need to look at the FEI as 80% of the environmental impacts of today's products and services are determined at the early stages of their development (Sherwin, 2017). Nonetheless, sustainability is often added-on at later phases, for instance, on operational developments and detailing stages; after key decisions are made.

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Appendix A – List of Papers Consulted for the Integrative Literature Review

Year	Title	Authors	Source Title
2015	Thinking patterns and gut feeling in technology identification and evaluation	Scheiner C.W., Baccarella C.V., Bessant J., Voigt K.-I.	Technological Forecasting and Social Change
2015	Usefulness simulation of design concepts	Bekhradi A., Yannou B., Farel R., Zimmer B., Chandra J.	Journal of Mechanical Design, Transactions of the ASME
2015	Decision making at the front end of innovation: The hidden influence of knowledge and decision criteria	de Oliveira M.G., Rozenfeld H., Phaal R., Probert D.	R and D Management
2015	How ideation portfolio management influences front-end success	Kock A., Heising W., Gemünden H.G.	Journal of Product Innovation Management
2015	Opening the black box of the role of accounting practices in the fuzzy front-end of product innovation	Carlsson-Wall M., Kraus K.	Industrial Marketing Management
2015	Assessment of foundational elements of the front-end in Brazilian small-size firms	Leon-Trujillo I.N.	Knowledge Management
2015	Key differences and similarities in ways of managing and supporting radical pharmaceutical front end innovation - A case study of the pharmaceutical industry	Aagaard A.	International Journal of Innovation Management
2015	Interdependency, dynamism, and variety (IDV) network modeling to explain knowledge diffusion at the fuzzy front-end of innovation	Gupta S., Maltz E.	Journal of Business Research

Year	Title	Authors	Source Title
2015	Knowing communities in the front end of innovation	Harvey J.-F., Cohendet P., Simon L., Borzillo S.	Research Technology Management
2015	Searching for radical new product ideas: Exploratory and confirmatory factor analysis for construct validation	Nicholas J., Ledwith A., Aloini D., Martini A., Nosella A.	International Journal of Technology Management
2015	Front-end service innovation: Learning from a design-assisted experimentation	Jevnaker B.H., Tellefsen B., Lüders M.	European Journal of Innovation Management
2015	The front end of innovation: Organizing search for ideas	Van Den Ende J., Frederiksen L., Prencipe A.	Journal of Product Innovation Management
2015	Innovating the innovation process: An organisational experiment in global pharma pursuing radical innovation	Robbins P., O'Gorman C.	R and D Management
2015	Research on process of generating NDI ideas for products driven by design and resources	Guo J., Tan R.-H., Sun J.-G., Cao G.-Z.	Chinese Journal of Engineering Design
2015	A climate of psychological safety enhances the success of front end teams	Nienaber A.-M.I., Holtorf V., Leker J., Schewe G.	International Journal of Innovation Management
2015	Novelty-focussed document mapping to identify new service opportunities	Lee C., Lee H.	Service Industries Journal
2015	Developing global service innovation capabilities :How global manufacturers address the challenges of market heterogeneity	Parida V., Sjödin D.R., Lenka S., Wincent J.	Research Technology Management
2015	Design resilience in the fuzzy front end (FFE) context: An empirical examination	Alblas A., Jayaram J.	International Journal of Production Research
2015	Making innovation happen in a megaproject: London's crossrail suburban railway system	Davies A., Macaulay S., Debarro T., Thurston M.	Project Management Journal
2015	Toward the development of new product ideas: Asymmetric effects of team cohesion on new product ideation	Hirunyawipada T., Paswan A.K., Blankson C.	Journal of Business and Industrial Marketing
2014	Contextual innovation management using a stage-gate platform: The case of philips shaving and beauty	Van Der Duin P.A., Ortt J.R., Aarts W.T.M.	Journal of Product Innovation Management

Year	Title	Authors	Source Title
2014	The front-end of eco-innovation for eco-innovative small and medium sized companies	Bocken N.M.P., Farracho M., Bosworth R., Kemp R.	Journal of Engineering and Technology Management - JET-M
2014	Applying agile project management to predevelopment stages of innovation	Gonzalez W.	International Journal of Innovation and Technology Management
2014	Small- to medium-size biotech firms' marketing efforts during the fuzzy front end of innovation	Schoonmaker M.G., Rau P.A.	Journal of Medical Marketing
2014	Innovation empathy: A framework for customer-oriented lean innovation	Montonen T., Eriksson P., Asikainen I., Lehtimäki H.	International Journal of Entrepreneurship and Innovation Management
2014	Fuzzy Front End and Commercialization: Cross-Cultural Differences, Similarities, and Paradoxes in Innovation Strategies and Practices	Godoe H., Vigrestad J., Miller R.	Journal of the Knowledge Economy
2014	Serial Innovators' processes: How they overcome barriers to creating radical innovations	Griffin A., Price R.L., Vojak B.A., Hoffman N.	Industrial Marketing Management
2014	Towards risk-aware roadmapping: Influencing factors and practical measures	Ilevbare I.M., Probert D., Phaal R.	Technovation
2014	Customer co-creation projects and social media: The case of Barilla of Italy	Martini A., Massa S., Testa S.	Business Horizons
2014	Research on ideas generation process for mechanical product radical innovation based on TRIZ	Ping E., Tan R., Sun J.	Zhongguo Jixie Gongcheng/China Mechanical Engineering
2014	Best practice project management: An analysis of the front end of the innovation process in the medical technology industry	Giles T., Cormican K.	International Journal of Information Systems and Project Management
2014	Innovative behaviour types and their influence on individual crowdsourcing performances	Zhu H., Djurjagina K., Leker J.	International Journal of Innovation Management
2014	Divergent thinking and market visioning competence: An early front-end radical innovation success typology	Reid S.E., de Brentani U., Kleinschmidt E.J.	Industrial Marketing Management

Year	Title	Authors	Source Title
2013	The impact of front-end innovation activities on product performance	Markham S.K.	Journal of Product Innovation Management
2013	The role of marketing activities in the fuzzy front end of innovation: A study of the biotech industry	Schoonmaker M., Carayannis E., Rau P.	Journal of Technology Transfer
2013	User typologies and research approaches for successful product and service innovations	Pichyangkul C., Israsena P.	Kasetsart Journal - Social Sciences
2013	Value driven innovation in medical device design: A process for balancing stakeholder voices	De Ana F.J., Umstead K.A., Phillips G.J., Conner C.P.	Annals of Biomedical Engineering
2013	A theoretical model of supporting open source front end innovation through idea management	Aagaard A.	International Journal of Business Innovation and Research
2013	Use of an innovation board to integrate the front end of innovation with formal NDP processes: A longitudinal study: An innovation board can help move promising ideas from the front end into development	Markham S.K., Lee H.	Research Technology Management
2013	Managing front-end innovation through idea markets at Novozymes: Idea markets stimulate creativity and enable recombination of existing knowledge in large corporations	Lauto G., Valentin F., Hatzack F., Carlsen M.	Research Technology Management
2013	An Exploration of New Product Development's Front-end Knowledge Conceptualization Process in Discontinuous Innovations	Akbar H., Tzokas N.	British Journal of Management
2013	Employees' Communication Patterns in Unorganized Idea-sharing Activities	Vrgovic P., Vidicki P., Senk V.	International Journal of Industrial Engineering and Management
2013	Boosting creativity with transformational leadership in fuzzy front-end innovation processes	Hyypiä M., Parjanen S.	Interdisciplinary Journal of Information, Knowledge, and Management
2013	Structuring the early fuzzy front-end to manage ideation for new product development	Riel A., Neumann M., Tichkiewitch S.	CIRP Annals - Manufacturing Technology

Year	Title	Authors	Source Title
2013	Interpretative dimension of user-driven service innovation: Forum Theatre in facilitating renewal in Finnish public health care	Pässilä A., Oikarinen T., Parjanen S., Harmaakorpi V.	Baltic Journal of Management
2013	The process and application of product innovation driven by FFE	Jiang P., Sun J.-G., Zhang H.-G., Tan R.-H.	Jisuanji Jicheng Zhizao Xitong/Computer Integrated Manufacturing Systems, CIMS
2013	Study on process of sustainable function innovation and its software development	Cao G.-Z., Guo H.-X., Tan R.-H., Liu H.-X.	Jisuanji Jicheng Zhizao Xitong/Computer Integrated Manufacturing Systems, CIMS
2013	Consumer co-creation and new product development: A case study in the food industry	Filieri R.	Marketing Intelligence and Planning
2013	Observations from radical innovation projects considering the company context	Yannou B., Jankovic M., Leroy Y., Okudan Kremer G.E.	Journal of Mechanical Design, Transactions of the ASME
2013	The relationship between innovation culture and innovation performance	Hilmarsson E., Oskarsson G., Gudlaugsson T.	International Journal of Business Research
2013	Antecedents and consequences of creativity in product innovation teams	Im S., Montoya M.M., Workman Jr. J.P.	Journal of Product Innovation Management
2013	Fuzzy decision support for tools selection in the core front end activities of new product development	Achiche S., Appio F.P., McAloone T.C., Di Minin A.	Research in Engineering Design
2012	A 'living laboratory' environment for exploring innovative RFID-enabled supply chain management models	Bendavid Y., Cassivi L.	International Journal of Product Development
2012	Brokerage functions in a virtual idea generation platform: Possibilities for collective creativity?	Parjanen S., Hennala L., Konsti-Laakso S.	Innovation: Management, Policy and Practice
2012	The role of social software for customer co-creation: Does it change the practice for innovation?	Martini A., Massa S., Testa S.	International Journal of Engineering Business Management
2012	The Contribution of Innovation Strategy Development and Implementation in Active Facilitation of Pharmaceutical Front End Innovation	Aagaard A.	Systemic Practice and Action Research

Year	Title	Authors	Source Title
2012	How to develop product-service systems in the fuzzy front end of innovation	Wagner L., Baureis D., Warschat J.	International Journal of Technology Intelligence and Planning
2012	Exploring radical innovation search practices	Ledwith A., Martini A., Nicholas J., Nosella A.	International Journal of Technology Intelligence and Planning
2012	Innovation in UK companies. An evaluation of the implementation of best practice in front end innovation processes and methodologies	Trotter P., Vaughan J.	International Journal of Innovation Science
2012	Managing new product development in the Brazilian medical device small and medium enterprises	Mendes G.H.S., de Toledo J.C.	Espacios
2012	Idea Management in support of Pharmaceutical Front End of Innovation	Aagaard A.	International Journal of Technology, Policy and Management
2012	Supporting empathetic boundary spanning in participatory workshops with scenarios and personas	Salmi A., Pöyry-Lassila P., Kronqvist J.	International Journal of Ambient Computing and Intelligence
2012	Distributed idea screening in stage-gate development processes	Onarheim B., Christensen B.T.	Journal of Engineering Design
2012	Improving performance evaluation metrics to manage innovative projects	Boly V., Morel L., Camargo M.	International Journal of Technology Intelligence and Planning
2012	Leveraging synergies between R&D and key account management to drive value creation	Wießmeier G.F.L., Thoma A., Senn C.	Research Technology Management
2012	Crowdsourcing	Schweitzer F.M., Buchinger W., Gassmann O., Obrist M.	Research Technology Management
2012	Tapping Supplier Innovation	Wagner S.M.	Journal of Supply Chain Management
2012	Knowledge flow at the fuzzy front-end of inter-firm RandD collaborations - Insights into SMEs in the pharmaceutical industry	Braun A., Mueller E., Adelhelm S., Vladova G.	International Journal of Entrepreneurship and Innovation Management

Year	Title	Authors	Source Title
2012	Strategic management of innovation: Managing exploration-exploitation by balancing creativity and constraint	Sætre A.S., Brun E.	International Journal of Innovation and Technology Management
2012	Guerrilla innovation - The accelerated radical innovation model meets the real world	Bers J.A., Dismukes J.P.	International Journal of Innovation and Technology Management
2012	Enhancing product innovation through a customer-centered, lean framework	Welo T., Olsen T.O., Gudem M.	International Journal of Innovation and Technology Management
2012	The fuzzy front-end of discontinuous innovation: Insights for research and management	De Brentani U., Reid S.E.	Journal of Product Innovation Management
2012	Market vision and the front end of NPD for radical innovation: The impact of moderating effects	Reid S.E., De Brentani U.	Journal of Product Innovation Management
2012	Collective intelligence with web-based information aggregation markets: The role of market facilitation in idea management	Bothos E., Apostolou D., Mentzas G.	Expert Systems with Applications
2011	Use of evaluation criteria and innovation performance in the front end of innovation	Martinsuo M., Poskela J.	Journal of Product Innovation Management
2011	Communities of practice versus organizational climate: Which one matters more to dispersed collaboration in the front end of innovation?	Bertels H.M.J., Kleinschmidt E.J., Koen P.A.	Journal of Product Innovation Management
2011	Challengingfront-end-of-innovation in information systems	Hannola L., Ovaska P.	Journal of Computer Information Systems
2011	Where process development begins: A multiple case study of front end activities in process firms	Kurkkio M., Frishammar J., Lichtenthaler U.	Technovation
2011	Beyond managing uncertainty: Insights from studying equivocality in the fuzzy front end of product and process innovation projects	Frishammar J., Florén H., Wincent J.	IEEE Transactions on Engineering Management
2011	Supporting the ideation processes by a collaborative online based toolset	Hesmer A., Hribernik K.A., Baalsrud Hauge J.M., Thoben K-D.	International Journal of Technology Management

Year	Title	Authors	Source Title
2011	Challenges of multi-actor involvement in the public sector front-end innovation processes: Constructing an open innovation model for developing well-being services	Hennala L., Parjanen S., Uotila T.	European Journal of Innovation Management
2011	Creating technology candidates for disruptive innovation: Generally applicable R & D strategies	Yu D., Hang C.C.	Technovation
2011	Information use in new product development: An initial exploratory empirical investigation in the chemical industry	Zahay D., Griffin A., Fredericks E.	Journal of Product Innovation Management
2011	Front end innovation and stakeholder involvement in machine tools sector	Pittino D., Visintin F., Compagno C.	International Journal of Entrepreneurship and Innovation Management
2011	Transforming lead user innovations into new corporate ventures: A matter of information asymmetry?	Fuchs B.	International Journal of Entrepreneurship and Innovation Management
2011	The integrative role of the project management office in the front end of innovation	Artto K., Kulvik I., Poskela J., Turkulainen V.	International Journal of Project Management
2011	Computer-aided embodiment design through the hybridization of mono objective optimizations for efficient innovation process	Cardillo A., Cascini G., Frillici F., Rotini F.	Computers in Industry
2011	Front end of innovation of high technology industries: The moderating effect of front-end fuzziness	Ho Y.-C., Tsai C.-T.	Journal of High Technology Management Research
2011	Managing the fuzzy front-end: Insights from process firms	Kurkkio M.	European Journal of Innovation Management
2011	From innovation to market entry: A strategic management model for new technologies	Kunz V.D., Warren L.	Technology Analysis and Strategic Management
2011	Attractive quality for requirement assessment during the front-end of innovation	Rejeb H.B., Boly V., Morel-Guimaraes L.	TQM Journal

Year	Title	Authors	Source Title
2011	The impact of front end innovation in new product development in Japanese manufacturing companies	Cao Y., Zhao L., Nagahira A.	Nankai Business Review International
2011	How many and what kind? the role of strategic orientation in new product ideation	Spanjol J., Qualls W.J., Rosa J.A.	Journal of Product Innovation Management
2011	Managing inter-firm collaboration in the fuzzy front-end: Structure as a two-edged sword	Jörgensen J.H., Bergenholtz C., Goduscheit R.C., Rasmussen E.S.	International Journal of Innovation Management
2011	A starting point for addressing product innovativeness in the Fuzzy Front-End	Oliveira M.G., Phaal R., Probert D., Cunha V.P., Rozenfeld H.	International Journal of Technology Intelligence and Planning
2011	The creation of novel and marketable service ideas	Chang C.M.	International Journal of Innovation and Technology Management
2010	A model for corporate renewal requirements for innovation management	Apilo T.	VTT Publications
2010	Elucidating the fuzzy front end experiences from the INNORISK project	Paasi J., Valkokari P.	VTT Publications
2010	Using a company brainstorm for employee-driven innovation: A case study	Onarheim B.	Design Principles and Practices
2010	Integrating technology roadmapping and portfolio management at the front-end of new product development	Oliveira M.G., Rozenfeld H.	Technological Forecasting and Social Change
2010	The impact of changing markets and competition on the NPD speed/market success relationship	Millson M.R., Wilemon D.	International Journal of Innovation Management
2010	Opening the fuzzy front-end of new product development: A synthesis of two theories	Kutvonen A., Torkkeli M.T.	International Journal of Business Excellence
2010	The role of new product development briefs in implementing sustainability: A case study	Petala E., Wever R., Dutilh C., Brezet H.	Journal of Engineering and Technology Management - JET-M
2010	Crossing horizons: Leveraging cross-industry innovation search in the front-end of the innovation process	Brunswicker S., Hutschek U.	International Journal of Innovation Management

Year	Title	Authors	Source Title
2010	How to create and sustain an open and radical innovation capability in the fuzzy front end: The case of Vodafone Group R&D Germany and selected ongoing radical innovation projects	Stüer C., Hüsing S., Biala S.	International Journal of Product Development
2010	With a little help from our colleagues: A longitudinal study of social networks for innovation	Kijkuit B., van den Ende J.	Organization Studies
2010	The valley of death as context for role theory in product innovation	Markham S.K., Ward S.J., Aiman-Smith L., Kingon A.I.	Journal of Product Innovation Management
2010	The role of globalization in new product development	Ozer M., Cebeci U.	IEEE Transactions on Engineering Management
2010	The front end of innovation - A group method for the elicitation of software requirements	Hannola L., Nikula U., Leino K., Tuominen M., Kälviäinen H.	International Journal of Innovation and Learning
2010	A living laboratory for managing the front-end phase of innovation adoption: the case of RFID implementation	Bendavid Y., Bourgault M.	International Journal of Project Organisation and Management
2009	A structural equation model of the impact of the "fuzzy front end" on the success of new product development	Verworn B.	Research Policy
2009	Management control and strategic renewal in the front end of innovation	Poskela J., Martinsuo M.	Journal of Product Innovation Management
2009	The future of computer-aided innovation	Leon N.	Computers in Industry
2009	Utilizing front-end-of-innovation concepts in software development	Hannola L., Kortelainen S., Kärkkäinen H., Tuominen M.	Industrial Management and Data Systems
2009	Exploring the contributions of involving ordinary users in ideation of technology-based services	Magnusson P.R.	Journal of Product Innovation Management
2009	Actualization process for product innovation in the phase of fuzzy front end	Liu X.-M., Tan R.-H., Yao L.-G., Chen C.-J., Jian Z.-H.	Jisuanji Jicheng Zhizao Xitong/Computer Integrated Manufacturing Systems, CIMS

Year	Title	Authors	Source Title
2009	Managing the Front end of innovation with a group support system	Elfvengren K., Kortelainen S., Tuominen M.	International Journal of Entrepreneurship and Innovation Management
2009	Integration of market pull and technology push in the corporate front end and innovation management-Insights from the German software industry	Brem A., Voigt K.-I.	Technovation
2009	A clean sweep	Weaver T.	Engineering
2009	Designing for other people's strengths and motivations: Three cases using context, visions, and experiential prototypes	Stappers P.J., van Rijn H., Kistemaker S.C., Hennink A.E., Sleeswijk Visser F.	Advanced Engineering Informatics
2009	A GSS process to generate new product ideas and business concepts	Elfvengren K., Kortelainen S., Tuominen M.	International Journal of Technology Management
2008	Gestion estrategica de la tecnologia en el predesarrollo de nuevos productos	Zapata A.R.P., Cantú S.O.	Journal of Technology Management and Innovation
2008	Exploratory roadmapping for foresight	Beeton D.A., Phaal R., Probert D.R.	International Journal of Technology Intelligence and Planning
2008	Critical success factors for the fuzzy front end of innovation in the medical device industry	Russell R.K., Tippett D.D.	EMJ - Engineering Management Journal
2008	Study on patterns of idea generation for fuzzy front end using TRIZ	Tan R., Yang B., Zhang J.	Zhongguo Jixie Gongcheng/China Mechanical Engineering
2008	Assessing infrastructure project innovation potential as a function of procurement mode	Tawiah P.A., Russell A.D.	Journal of Management in Engineering
2008	Improving the front end of innovation with information technology	Gordon S., Tarafdar M., Cook R., Maksimoski R., Rogowitz B.	Research Technology Management
2008	Systematic method to generate new ideas in fuzzy front end using TRIZ	Tan R., Ma L., Yang B., Sun J.	Chinese Journal of Mechanical Engineering (English Edition)
2008	Architectural knowledge in inter-organizational IT innovation	Andersson M., Lindgren R., Henfridsson O.	Journal of Strategic Information Systems

Year	Title	Authors	Source Title
2008	Maximizing productivity in product innovation	Cooper R.G., Edgett S.J.	Research Technology Management
2008	Competing for defence ideas: Looking wider for innovation	[No author name available]	Strategic Direction
2008	The fuzzy front end of Japanese new product development projects: Impact on success and differences between incremental and radical projects	Verworn B., Herstatt C., Nagahira A.	R and D Management
2008	Advanced product planning: A comprehensive process for systemic definition of new product requirements	Agouridas V., McKay A., Winand H., de Pennington A.	Requirements Engineering
2007	Supporting the sytematization of early-stage-innovation by means of collaborative working environments	Hesmer A., Hribernik K.A., Hauge J.B., Thoben K.-D.	IFIP International Federation for Information Processing
2007	Conceptualizing, assessing, and managing front-end fuzziness in innovation/NPD projects	Chang S.-L., Chen C.-Y., Wey S.-C.	R and D Management
2007	Reducing the demand uncertainties at the fuzzy-front-end of developing new online services	Ozer M.	Research Policy
2007	An object-oriented reference model of the fuzzy front end of the new product introduction process	Williams M.A., Kochhar A.K., Tennant C.	International Journal of Advanced Manufacturing Technology
2007	Possibility thinking: Lessons from breakthrough engineering	Friedel R., Liedtka J.	Journal of Business Strategy
2007	New product market visioning in small enterprises: A preliminary empirical study within the Central Technology Belt in England	Shiu E., Walker D.	Journal of Small Business and Enterprise Development
2007	Working with concepts in the fuzzy front end: Exploring the context for innovation for different types of concepts at Volvo Cars	Backman M., Börjesson S., Setterberg S.	R and D Management
2006	New technologies for public sector transformation: A critical analysis of e-government initiatives in Latin America and the Caribbean	Rubino-Hallman S., Hanna N.K.	Journal of E-Government

Year	Title	Authors	Source Title
2006	The front end of innovation in an era of industry convergence: Evidence from nutraceuticals and functional foods	Bröring S., Cloutier L.M., Leker J.	R and D Management
2006	Pharmaceutical discovery as a complex system of decisions: The case of front-loaded experimentation	van Dyck W., Allen P.M.	E:CO Emergence: Complexity and Organization
2006	Life-cycle flexibility: How to measure and improve the innovative capability in turbulent environments	Buganza T., Verganti R.	Journal of Product Innovation Management
2006	Removing the fuzziness from the fuzzy front-end of service innovations through customer interactions	Alam I.	Industrial Marketing Management
2006	Extreme customer innovation in the front-end: Learning from a new software paradigm	Gassmann O., Sandmeier P., Wecht C.H.	International Journal of Technology Management
2006	Fuzzy front-end practices in innovating Japanese companies	Herstatt C., Stockstrom C., Verworn B., Nagahira A.	International Journal of Innovation and Technology Management
2005	Re-engineering service quality process mapping: E-banking process	Akamavi R.K.	Marketing Intelligence and Planning
2004	Organisation of the early phases of the radical innovation process	Lichtenthaler E., Savioz P., Birkenmeier B., Brodbeck H.	International Journal of Technology Intelligence and Planning
2004	Reducing project related uncertainty in the ‘fuzzy front end’ of innovation: a comparison of German and Japanese product innovation projects	Herstatt C., Verworn B., Nagahira A.	International Journal of Product Development
2004	Reengineering based inquiry into innovation in the front end of new product and service development processes	McAdam R., Leonard D.	International Journal of Product Development
2003	Piloting the rocket of radical innovation	Stevens G.A., Burley J.	Research Technology Management
2002	Exploratory research remains essential for industry	Beall G.H.	Research Technology Management
2002	Focusing the fuzzy front-end in new product development	Kim J., Wilemon D.	R and D Management
2002	Optimizing the stage-gate process: What best-practice companies Do-I	Cooper R.G., Edgett S.J., Kleinschmidt E.J.	Research Technology Management

Year	Title	Authors	Source Title
2002	Performance-centered design of knowledge-intensive processes	Massey A.P., Montoya-Weiss M.M., O'Driscoll T.M.	Journal of Management Information Systems
2002	The idea and project database of WELLA AG	Geschka H., Lenk T., Vietor J.	International Journal of Technology Management
2001	Radical innovation: Triggering initiation of opportunity recognition and evaluation	Rice M.P., Kelley D., Peters L., O'Connor G.C.	R and D Management
2001	Providing clarity and a common language to the "fuzzy front end"	Koen P., Ajamian G., Burkart R., Clamen A., Davidson J., D'Amore R., Elkins C., Herald K., Incorvia M., Johnson A., Karol R., Seibert R., Slavejkov A., Wagner K.	Research Technology Management
2001	High Touch - An innovative scheme for new product development: Case studies 1994-1998	Lee M.W., Yun M.H., Han S.H.	International Journal of Industrial Ergonomics
2000	New product introduction practices in the British manufacturing industry	Williams M.A., Kochhar A.K.	Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture
2000	Managing learning in informal innovation networks: Overcoming the Daphne-dilemma	Van Aken J.E., Weggeman M.P.	R and D Management
1999	Front-end innovation at AlliedSignal and Alcoa	Smith G.R., Herbein W.C., Morris R.C.	Research Technology Management
1998	Information processing approach for facilitating the fuzzy front end of breakthrough innovations	Leifer Richard	IEEE International Engineering Management Conference
1998	Idea generation: who has the most profitable ideas	Koen P.A., Kohli P.	EMJ - Engineering Management Journal
1998	Towards holistic "front ends" in new product development	Khurana A., Rosenthal S.R.	Journal of Product Innovation Management
1997	From experience: Dreams to market: Crafting a culture of innovation	Zien K.A., Buckler S.A.	Journal of Product Innovation Management

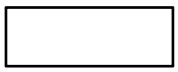
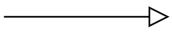
Year	Title	Authors	Source Title
1995	At the front end of the R&D/innovation process	Rubenstein Albert H.	IEEE Engineering Management Review
1995	R&D/Marketing Communication During the Fuzzy Front-End	Moenaert R.K., Meyer A.D., Souder W.E., Deschoolmeester D.	IEEE Transactions on Engineering Management

Appendix B – UML Notation

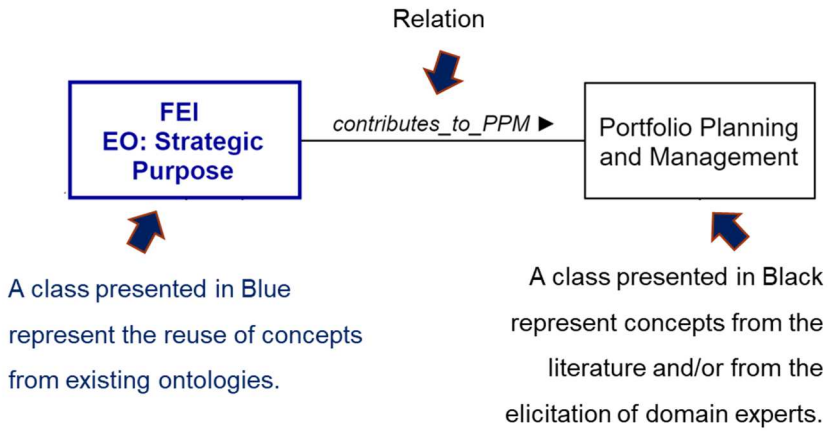
The Unified Modelling Language (UML) is characteristic in the field of software engineering. This language is understood as of a general-purpose that provides a standard way to visualise the design of a system. Although it is to completely back up for formal logic, it is still a formal language in the sense that fixpoint, model-theoretic or operational semantics are defined for it. Therefore, it is less ambiguous than a natural language representation (Evermann, 2009).

Following it is presented the main notation applied in the FEI Integrative Ontology.

B.1 Unified Modelling Language Notation

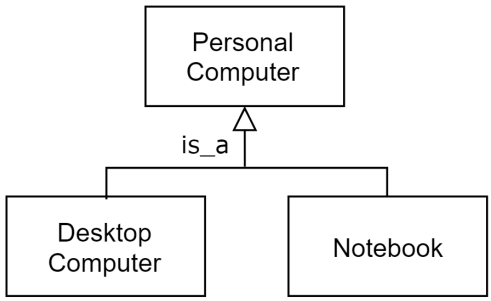
Concept	**Definition**	**Notation**
Class	Description of a set of concepts that share the same characteristic property.	
Association	Description of a set of concepts that share the same characteristic property.	
Inheritance	Inheritance refers to the ability of a class (child class) to inherit the identical functionalities of another class (super class), and then add new functionalities of its own.	
Aggregation	A special form of association which specifies an all-part relation between the whole and its parts, in such a way that its parts in the whole are interrelated.	

B.2 Example of Class and Association



B.3 Example of Inheritance

An example of representation in UML:



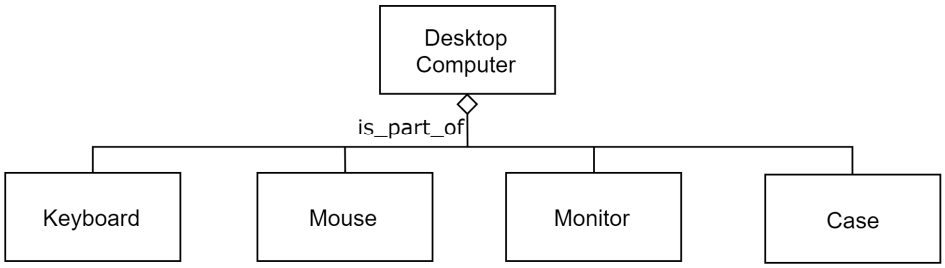
An example of representation in natural language:

Desktop Computer **IS_A** Personal Computer

Notebook **IS_A** Personal Computer

B.4 Example of Aggregation

An example of representation in UML:



An example of representation in natural language:

Keyboard **IS_PART_OF** Personal Computer

Mouse **IS_PART_OF** Personal Computer

Monitor **IS_PART_OF** Personal Computer

Case **IS_PART_OF** Personal Computer

Appendix C – Evaluation Roadmap

C.1 Evaluation Roadmap Used in the Validation Phase

Thank you for considering taking part of this research. I kindly ask you to please answer the following questions. Your analysis will be of significant help for evaluating the FEI ontology.

Name of participant: _____ **Gender:** ( ) Male ( ) Female
Affiliation: _____ **Area of expertise / Position**: _____

1. Concerning the HIGH-LEVEL ONTOLOGY, please mark how strongly you agree or disagree with each of these criteria.

Criteria / Scale	**Strongly Agree**	**Agree**	**Neither Agree Nor Disagree**	**Disagree**	**Strongly Disagree**
Completeness (É exaustiva)	( )	( )	( )	( )	( )
Comprehensives (É abrangente)	( )	( )	( )	( )	( )
Utility (É útil)	( )	( )	( )	( )	( )
Consistency (É consistente)	( )	( )	( )	( )	( )
Understandability (É compreensível)	( )	( )	( )	( )	( )

2. Concerning the FEI PURPOSE SUB-ONTOLOGY, please mark how strongly you agree or disagree with each of these criteria.

Criteria / Scale	**Strongly Agree**	**Agree**	**Neither Agree Nor Disagree**	**Disagree**	**Strongly Disagree**
Completeness (É exaustiva)	( )	( )	( )	( )	( )
Comprehensives (É abrangente)	( )	( )	( )	( )	( )
Utility (É útil)	( )	( )	( )	( )	( )
Consistency (É consistente)	( )	( )	( )	( )	( )
Understandability (É compreensível)	( )	( )	( )	( )	( )

3. Concerning the SUB-ONTOLOGY PORTFOLIO PLANNING & MANAGEMENT, please mark how strongly you agree or disagree with each of these criteria.

Criteria / Scale	**Strongly Agree**	**Agree**	**Neither Agree Nor Disagree**	**Disagree**	**Strongly Disagree**
Completeness (É exaustiva)	( )	( )	( )	( )	( )
Comprehensives (É abrangente)	( )	( )	( )	( )	( )
Utility (É útil)	( )	( )	( )	( )	( )
Consistency (É consistente)	( )	( )	( )	( )	( )
Understandability (É compreensível)	( )	( )	( )	( )	( )

4. Concerning the SUB-ONTOLOGY FEI STAGE, please mark how strongly you agree or disagree with each of these criteria.

Criteria / Scale	**Strongly Agree**	**Agree**	**Neither Agree Nor Disagree**	**Disagree**	**Strongly Disagree**
Completeness (É exaustiva)	( )	( )	( )	( )	( )
Comprehensives (É abrangente)	( )	( )	( )	( )	( )
Utility (É útil)	( )	( )	( )	( )	( )
Consistency (É consistente)	( )	( )	( )	( )	( )
Understandability (É compreensível)	( )	( )	( )	( )	( )

5. Concerning the FEI AGILE DEVELOPMENT PROCESS, please mark how strongly you agree or disagree with each of these criteria.

Criteria / Scale	**Strongly Agree**	**Agree**	**Neither Agree Nor Disagree**	**Disagree**	**Strongly Disagree**
Completeness (É exaustiva)	( )	( )	( )	( )	( )
Comprehensives (É abrangente)	( )	( )	( )	( )	( )
Utility (É útil)	( )	( )	( )	( )	( )
Consistency (É consistente)	( )	( )	( )	( )	( )
Understandability (É compreensível)	( )	( )	( )	( )	( )

6. Concerning the FEI ACTORS, please mark how strongly you agree or disagree with each of these criteria.

Criteria / Scale	**Strongly Agree**	**Agree**	**Neither Agree Nor Disagree**	**Disagree**	**Strongly Disagree**
Completeness (É exaustiva)	( )	( )	( )	( )	( )
Comprehensives (É abrangente)	( )	( )	( )	( )	( )
Utility (É útil)	( )	( )	( )	( )	( )
Consistency (É consistente)	( )	( )	( )	( )	( )
Understandability (É compreensível)	( )	( )	( )	( )	( )

In your opinion the FEI Integrative Ontology <u>answered</u> the following Competence Questions?

1. Does the ontology allow the identification of the knowledge domains present in the FEI? / A ontologia permite identificar os domínios de conhecimento presentes no FEI?

( ) Yes, it answered this question ( ) No, it did not answer this question

2. Which are the outcomes (results) of the FEI Integrative Ontology? / Quais são as saídas (resultados) da Ontologia Integradora do FEI?

( ) Yes, it answered this question ( ) No, it did not answer this question

3. Which processes unfold in the context of the FEI Ontology? / Quais processos se desenrolam no contexto da ontologia do FEI?

( ) Yes, it answered this question ( ) No, it did not answer this question

4. Which are the stages related to the new concept development? / Quais são os estágios relacionados ao desenvolvimento de um novo conceito?

( ) Yes, it answered this question ( ) No, it did not answer this question

5. Which are the outputs of the FEI Agile New Concept Development? / Quais são os resultados do FEI Agile Desenvolvimento de Novo Conceito?

( ) Yes, it answered this question ( ) No, it did not answer this question

6. Who are the actors in the FEI? / Quem são os atores no FEI?

( ) Yes, it answered this question ( ) No, it did not answer this question

7. Which are the roles played by FEI actor´s? / Quais são os papéis desempenhados por atores do FEI?

( ) Yes, it answered this question ( ) No, it did not answer this question

GLOSSARY

THE HIGH-LEVEL ONTOLOGY: Inter-domain Key Relationships	
Concept	**Definition**
FEI EO: Strategic Purpose	A purpose held by an actor that is declared to be of ``strategic'' importance (Uschold et al., 1998), in this case, an FEI Strategic Purpose.
Portfolio Planning & Management – PP&M	A well-planned portfolio is one precondition to have a foundation for streams of successful new products (Khurana and Rosenthal, 1997). Project Portfolio Management can be described as a dynamic process in which the portfolio of active projects is subject to a periodic review and update. Moreover, it supports the evaluation, selection, prioritisation and control of the firm's project portfolio (Oliveira and Rozenfeld, 2010). The PP&M comprises a portfolio of new products, product strategy and organisational factors, which, according to Khurana and Rosenthal (1997), are elements responsible for providing a successful New Product Development.
FEI Agile New Concept Development	FEI Agile NCD represents an integrated and iterative development process in the FEI (The authors, 2016).
FEI EO: Actor	It is an entity that plays an actor role in a relationship (Uschold et al., 1998), in this case, actors that perform an activity in the FEI.
New Concept	The new concept is(are) the result(s) of the FEI, and it represents the input for the New Product/Service Development and further commercialization phase (Koen et al., 2002, The authors, 2017).

Sub-ontology FEI PURPOSE, *focus on* Opportunity	
Concept	**Definition**
Opportunity	Opportunity is understood as a “business or technology gap, that a company or individual realizes, that exists between the current situation and an envisioned future in order to capture competitive advantage, respond to a threat, solve a problem, or ameliorate a difficulty” (Koen et al, 2002, p. 7).
Opportunity recognition	It represents early and frequently uncertain technology and market assessments that will guide the beginning of the decision-making process in the FEI (Koen et al., 2002).
Opportunity Confidence	It represents the actor individual’s evaluation of external enablers and/or New Venture Ideas (Davidsson, 2015).

Sub-ontology FEI PURPOSE, *focus on* Opportunity	
Concept	**Definition**
Source of Opportunity	The sources of innovation account for internal and external opportunities. The potential for innovation may be found in more than one area at a time (Drucker, 2002).
Internal [Source of Opportunity]	The sources of innovation account for internal and external opportunities. The potential for innovation may be found in more than one area at a time (Drucker, 2002).
External [Source of Opportunity]	The sources of innovation account for internal and external opportunities. The potential for innovation may be found in more than one area at a time (Drucker, 2002).
CO: Requirement	It represents something that is necessary and needed (Leppänen, 2005).
CO: Threat	Threat is a situation or condition that is a risk for attainment of a goal (Leppänen, 2005)
CO: Strength	Strength means something in which one is good, something that is regarded as an advantage and thus increasing the possibilities to gain something better (Leppänen, 2005).
CO: Weakness	Weakness means something in which one is poor, something that could or should be improved or avoided (Leppänen, 2005).
CO: Problem	It is the distance or a mismatch between the prevailing state and the state reflected by the goal. They are the point of departure and the major source of New Venture Ideas, Goldkuhl et al. (1998); Jayaratna, (1994) apud Leppänen, (2005) (Wimmer, 2016).

Sub-ontology FEI PURPOSE	
Concept	**Definition**
[Business] EO: Purpose	Purpose denotes two related notions. The envisioned reason for executing an activity. Moreover, it is something that an Organisation Unit can be responsible for (Uschold et al., 1998), in this case, managed by the FEI process.
Formal [Purpose]	It represents something stated or agreed in writing (Business Dictionary, 2017). In this case, a formal Purpose.
Informal [Purpose]	It represents something that is not yet formal or official (Cambridge Dictionary, 2017). In this case, an Informal Purpose.
EO: Strategic Planning	It is a planning activity which purpose is to produce a strategy (Uschold et al., 1998, p. 56). The key concepts regarding Strategic Planning can be regarded as terms concerning decisions, assumptions, risks and various kinds of factors (Uschold et al., 1998).

Sub-ontology FEI PURPOSE	
Concept	**Definition**
FEI EO: Strategic Purpose	A purpose held by an actor that is declared to be of ``strategic'' importance (Uschold et al., 1998), in this case of strategic importance to the FEI.
EO: Goal	Goal, Mission and Vision: they are kinds of Purposes (Uschold et al., 1998). 1. They may or may not be Objectives. 2. Below it is indicated some ways that these terms may be specialised: - As the helps achieve relationship orders purposes, the order will tend to be: Goal, Mission, Vision (from lowest-level). - With respect to measurability, the order will tend to be: Goal, Mission, Vision (from most measurable). - With respect to time horizon, the order will tend to be: Goal, Mission, Vision (from shortest time horizon).
EO: Mission	
EO: Vision	
CO: Strategic goal	The strategic goal is regarded as a pattern in a stream of decision (Mintzberg, 1978).
CO: Tactic goal	Tactic goals show how to attain strategic goals (Leppänen, 2005).
CO: Operational goal	Operational goals are generally determined as concrete requirements that are to be fulfilled by a specific point in time (Leppänen, 2005).
Opportunity	Opportunity is understood as a “business or technology gap, that a company or individual realizes, that exists between the current situation and an envisioned future in order to capture competitive advantage, respond to a threat, solve a problem, or ameliorate a difficulty” (Koen et al, 2002, p. 7).
CO: Criterion	It is a standard of judgment presented as an established rule or principle for evaluating something (Leppänen, 2005).

Sub-ontology PORTFOLIO PLANNING & MANAGEMENT	
Concept	**Definition**
FEI EO: Strategic Purpose	A purpose held by an actor that is declared to be of ``strategic'' importance (Uschold et al., 1998), in this case, an FEI Strategic Purpose.
Formal [P&PS]	It represents something stated or agreed in writing (Business Dictionary, 2017), in this case, a Formal P&PS.
Informal [P&PS]	It represents something that is not yet formal or official (Cambridge Dictionary, 2017), in this case, an Informal P&PS.
Portfolio Planning & Management	A well-planned portfolio is one precondition to have a foundation for streams of successful new products (Khurana and Rosenthal, 1997). Project Portfolio Management can be described as a dynamic process in which the portfolio of active

Sub-ontology PORTFOLIO PLANNING & MANAGEMENT	
Concept	**Definition**
	projects is subject to a periodic review and update. Moreover, it supports the evaluation, selection, prioritisation and control of the firm's project portfolio. (Oliveira and Rozenfeld, 2010). The PP&M comprises a portfolio of new products, product strategy and organisational factors, which according to Khurana and Rosenthal (1997) are elements responsible for providing a successful New Product Development.
EO: Strategic Planning	It is a planning activity which purpose is to produce a strategy (Uschold et al., 1998, p. 56). The key concepts regarding Strategic Planning can be regarded as terms concerning decisions, assumptions, risks and various kinds of factors (Uschold et al., 1998).
Product & Portfolio Strategy	It is referred to the alignment between PP&M and Product & Portfolio Strategy; it is expected to enhance the articulation of core PP&M activities and Strategy (Khurana and Rosenthal, 1997).
Portfolio Planning	A Portfolio Planning process needs to collect and analyse internal and external information related to markets and technologies of interest to the firm/startup (Patterson, 2007, p. 49).
Portfolio Management	It concerns a set of activities including portfolio assessment, resource management, and portfolio review (Patterson, 2007).
Market Scanning	It refers to the function of making a firm aware of market opportunities (explicit and tacit), considering the context within industries that the firms operate. Moreover, it facilitates finding new opportunities outside the market segments currently on focus (Alam et al., 2013).
Technology Scanning	It refers to the function of making a firm aware of technological opportunities, which can be acquired or licensed from outside the firm, moreover, considers the using knowledge to develop the technology internally. Technology-scanning enables the discovery of a technological solution to an identified or anticipated customer problem (Alam et al, 2013).
Capability Development	It tackles the capabilities that a firm owns altogether with the capability gaps that need to be satisfied (Osterwalder et al., 2004).
Technology Roadmap	“Technology roadmapping serves to describe the market, to plan product and process development, to establish technological capacities and to analyse resources (Willyar and McClees, 1987) apud (Oliveira and Rozenfeld, 2007).”

Sub-ontology PORTFOLIO PLANNING & MANAGEMENT	
Concept	**Definition**
Product Roadmap	"Primary responsibility for the product roadmap will belong to the marketing function, whereas technology roadmap planning will belong to the R&D function. At various points in the process, these two functions should come together to share and integrate what they have learned. The resulting product roadmap will thus be responsive to R&D's understanding of technology developments, and technology strategies will reflect the firm's knowledge of current and future market factors (Patterson, 2007, p. 49)."

Sub-ontology PORTFOLIO PLANNING & MANAGEMENT *focus on* Organizational Factors	
Concept	**Definition**
Organizational Factors	Organisational Factors entails organisational resources, culture, team & collaboration, senior management involvement and structure (Koen et al., 2002; Koen et. al., 2014a, 2014b).
BMO: Resources	Resources are the means, which a company use to create value (Osterwalder et al., 2004).
BMO: Tangible Assets	A tangible assed correspond to a physical asset, which its value can be measured. "Tangible resources include plants, equipment and cash reserves." (Grant, 1991 apud Osterwalder, 2004; The authors, 2016).
BMO: Intangible Assets	Intangible assets are assets that an entrepreneurs or company has, but its not material. Examples include "patents, copyrights, reputation, brands and trade secrets." (Grant, 1991 apud Osterwalder, 2004; The authors, 2016).
BMO: People Based Skills	"Human resources are the people a firm needs in order to create value with tangible and intangible resources." (Grant, 1991 apud Osterwalder, 2004)
BMO: Capability	"A capability is the ability to execute a repeatable pattern of actions that is necessary in order to create value for the customer." (Osterwalder, 2004).
BMO: Partnership	It represents a voluntarily initiated cooperative agreement developed by two or more independent companies to carry out a project or specific activity cooperatively by coordinating the necessary capabilities, resources and activities (Osterwalder, 2004).
Capability Development	It tackles the capabilities that a firm owns altogether with the capability gaps that need to be satisfied (Osterwalder et al., 2004).
Culture	Culture can be regarded as "patterns of behavior, attitudes, and feelings within an organization". (Koen et al., 2014, p. 40).

Sub-ontology PORTFOLIO PLANNING & MANAGEMENT *focus on* Organizational Factors	
Concept	**Definition**
Team and Collaboration	Team and Collaboration can be exemplified by the following constructs effective teams, team leadership and Communities of Practice CoPs (Koen et al., 2014).
Senior Management Involvement	“The degree of involvement of senior managers are involved with front-end activities.” (Koen et al., 2014, p. 40).
Structure	The organisational structure may facilitate the product development. In this regard, it is necessary to consider the flow of communication and a cross-functional sharing of responsibilities to become effective (Khurana and Rosenthal, 1997).

Sub-Ontology FEI AGILE DEVELOPMENT PROCESS	
Concept	**Definition**
FEI Agile NCD	FEI Agile New Concept Development represents an integrated and iterative development in the FEI. This process may consist of successive iterations (The authors, 2016).
A: Agile Method	Agile methods place emphasis on being flexible to changes in requirements and working in collaboration with customers and other stakeholders (Parsons, 2011).
FEI Iteration	A formal definition of iteration is that it refers to the process of doing something, again and again, generally to improve it (Cambridge Dictionary, 2017). The FEI Iteration enables the arrangement of activities and resources that are necessary to the development of the new concept. Moreover, it eventually adjusts the FEI EO: Strategic Purpose, and offer feedback to the Portfolio Planning and Management (The authors, 2016).
FEI Stage	It represents the existing stages concerning the beginning of the innovation process. Considering stage as a group of concurrently accomplished tasks, with specified outcomes and deliverables (PDMA, 2016; The authors, 2016).
FEI EO: Strategic Purpose	A purpose held by an actor that is declared to be of ``strategic'' importance (Uschold et al., 1998), in this case, an FEI Strategic Purpose.
Portfolio Planning & Management	A well-planned portfolio is one precondition to have a foundation for streams of successful new products (Khurana and Rosenthal, 1997). Project Portfolio Management can be described as a dynamic process in which the portfolio of active projects is subject to a periodic review and update. Moreover, it supports the evaluation, selection, prioritisation and control of the firm's project portfolio. (Oliveira and Rozenfeld, 2010). The PP&M comprises a portfolio of new products,

Sub-Ontology FEI AGILE DEVELOPMENT PROCESS	
Concept	**Definition**
	product strategy and organisational factors, which according to Khurana and Rosenthal (1997) are elements responsible for providing a successful New Product Development.
New Concept	The new concept is the result of the FEI, and it is the input for the New Product/Service Development and further commercialization phase (Koen et al., 2002; The authors, 2017).
Build	This concept is based on the creation and development of hypothesis and experiments, building on primary and secondary information (Blank and Dorf, 2012; The authors, 2017)
Measure	The measure concept consists of measuring results of experiments and hypothesis (Blank and Dorf, 2012; The authors, 2017).
Learn	Learn is an important component of the learning cycle (Build – Measure – Learn) and it represents the learning process as result of the performed experiments (Blank and Dorf, 2012; The authors, 2017).
Iteration Information	A formal definition of iteration is that it refers to the process of doing something, again and again, generally to improve it (Cambridge Dictionary, 2017). Therefore, it represents the information gathering during each iteration on which it will be built knowledge to support each iteration (The authors, 2017).

Sub-ontology FEI STAGE	
Concept	**Definition**
FEI Stage	It represents the existing stages concerning the beginning of the innovation process. Considering stage as a group of concurrently accomplished tasks, with specified outcomes and deliverables (PDMA, 2016; the authors, 2016).
EO: Activity	Activity is intended to capture the notion of anything that involves actual doing, in particular including action.
CO: Tools	A tool is a thing that is designed, built, installed, etc. To serve in a specific action affording a convenience, efficiency or effectiveness (Leppänen, 2005).
Methodologies	A system of broad principles or rules from which specific methods or procedures may be derived to interpret or solve different problems within the scope of a particular discipline. Unlike an algorithm, a methodology is not a formula but a set of practices (Business Dictionary, 2016).
Preliminary Opport. Identification	It represents the identification of opportunities that an organization or an entrepreneur might want to pursue. Therefore, it includes ideation activities and also defines the market and/or technology arena that the organisation/startup may want to take part (Koen et al., 2002; The authors, 2017).

Sub-ontology FEI STAGE	
Concept	**Definition**
Product Concept Development	The product concept and definition are shaped. The concept definition still may be subject for fine-tuning. It is the responsibility of this stage to produce judgments about the target market, competitive landscape, and plans concerning expected time and resources needed for bringing the product to market. Thus, it is responsible for identifying customer and user needs/wants/fears, competitive scenario and technologies (Khurana and Rosenthal, 1997; The authors, 2017).
Feasibility and Project Planning	Feasibility analysis and project planning are important activities to help the business development. They play a vital role in supporting to determine the potential for success of a new concept or business venture (Hofstrand and Holz-Clause, 2016).
Business Model Development	A Business Model is conceptual, instead of a financial, a model of business, by which a company creates and delivers value to its customers, and the payment received for doing so is converted in profit (Teece, 2010).

Sub-Ontology FEI ACTORS	
Concept	**Definition**
EO: Actor	It is an entity that plays an actor role in a relationship (Uschold et al., 1998), in this case, actors that performs an activity in the FEI.
EO: Activity	Activity is intended to capture the notion of anything that involves actual doing, in particular including action. An activity can have happened in the past and may be happening in the present. The term can also be used to refer to a hypothetical future activity (Uschold et al. 1998).
Stakeholder	It can be understood as “any group or individual who can affect or is affected by the achievement of the organization's objectives” (Freeman, 1984, p. 46).
BMO: People Based Skill	Human resources are the people a firm needs in order to create value with tangible and intangible resources (Osterwalder et al., 2004).
EO: Organisational Unit	Organisational Unit refers to things that represent an organised whole which is perceived as more than the sum of its parts. Whether or not they are composite. OU has full recognition by an organisation, however, does not demand a legal character (Uschold et al. 1998).
Formal [Organisation Unit]	It represents something stated or agreed in writing (Business Dictionary, 2017). In this case, the formal Organisation Unit.

Sub-Ontology FEI ACTORS	
Concept	**Definition**
Informal [Organisation Unit]	It represents something that is not yet formal or official (Cambridge Dictionary, 2017). In this case, the Informal Organisation Unit.
EO: Machine	A non-human which has the capacity to carry out functions and/or play various roles in an enterprise (Uschold et al. 1998).
CO: Organisation	An organisation is an administrative arrangement or structure established for some purposes, manifesting the division of labour into actions and the coordination of actions to accomplish the work. It can be formal or informal (Leppänen, 2005; The authors, 2017).
Formal [Organisation]	It represents something stated or agreed in writing (Business Dictionary, 2017). In this case, the formal Organisation.
Informal [Organisation]	It represents something that is not yet formal or official (Cambridge Dictionary, 2017). In this case, the Informal Organisation.
CO: Position	A position is occupied by zero or many human actors. For each position, specific qualifications in terms of skills, demands on education, and experience, etc, are specified (Leppänen, 2005).
CO: Organisational Role	It is a collection of responsibilities, stipulated in an operational or structural manner (Leppänen, 2005).
T-shaped Specialist Role	It is considered specialist as a mean to represent any professional involved in the innovation process. It entails the notion that a T-shaped specialist is someone who shares knowledge freely across the organization (denoted by the horizontal part of the “T”). At the same time this professional has a strong specialized knowledge committed to a specific business unit performance (the vertical part) (Hansen and Oetinger, 2001).
Leadership Role	According to research findings, there are several leadership behaviours identified as influencers of people’s willingness to engage in innovative efforts (Rekonen and Björklund, 2015).
Innovator Role	It represents informal roles frequently found in the innovation literature. It is suggested that their activities set interacts with each other to cross the so-called "valley of death" (Markham et al., 2010).
Champion	Concerns someone that adopts and advocates a project (Markham et al., 2010).
Sponsor	Represents someone that provides project sanctioning and resources (Markham et al., 2010).

Sub-Ontology FEI ACTORS	
Concept	**Definition**
Gatekeeper	It is related to the role responsible for establishing criteria and making decisions concerning the future of the project (Markham et al., 2010).
Facilitator	It is a role that helps to bring about an outcome by providing indirect or unobtrusive assistance, guidance, or supervision (Webster, 2017).

Sub-Ontology FEI ACTORS *focus on* Stakeholder	
Concept	**Definition**
EO: Owner	Ownership is the union of legal ownership and non-legal ownership (Uschold et al. 1998).
EO: Shareholder	It stands for a legal entity owning one or more shares in a corporation (Uschold et al. 1998).
BMO: Value Network	The value network is composed of suppliers, partners and coalitions (Osterwalder et al., 2004).
BMO: Partner	Considering partners as those who supply complements to a final product or solution (Osterwalder et al., 2004).
BMO: Coalition	Coalitions are alliances with like-minded competitors (Osterwalder et al., 2004).
BMO: Supplier	Supplier is an entity that provides something needed such as a product or service (Osterwalder et al., 2004).
Media	Mass communication technology has changed the role of the media with regard to business, therefore it is an important Stakeholder to be considered (Freeman, 1984).
Environmentalists	Environmental protection agencies and others institutionalized environmental initiatives are example of environmentalists' stakeholders (Freeman, 1984).
Special Interest Groups	Special Interest Group may also be recognised as Social Interest Groups or Single Issue Politics. The idea here is that a group or an individual can use the political process to further a position on a particular issue (Freeman, 1984).
Entrepreneur	It is the person responsible for driving the creation of a new venture (Wimmer, 2016).
Employees	A person who works part-time or full-time under a contract of employment and has recognised rights and duties (Business Dictionary, 2017).
Customer	A party (eventually called as a client) that receives or consumes products (goods or services) and has the ability to choose between different products and suppliers (Business Dictionary, 2017; The authors, 2017).

Sub-Ontology <u>FEI ACTORS *focus on* Stakeholder</u>	
Concept	**Definition**
User	A user is an entity that has authority to use an application, equipment, facility, process, or system. Additionally, it may be considered as one who consumes or employs a good or service to obtain a benefit or to solve a problem, and who may or may not be the actual purchaser of the item (Business Dictionary, 2017).
Lead User	A Lead User represents someone that is at the leading edge of an important market trend. A Lead User has a high need for solutions to the novel needs he/she has encountered at that leading edge (von Hippel et al., 2009).
Government	There are several possible interactions among businesses and government actors that impact the company (Freeman, 1984).
Community	It is the local community organised (Freeman, 1984).

Appendix D Consent Form

D.1 Focus Group Consent Form

Thesis: Front End of Innovation (FEI) Integrative Ontology: A Design Science Approach
PhD Student: Ariane Rodrigues Pereira
Advisors: Prof. João José Pinto Ferreira and Prof. Alexandra Lopes
Doctoral Program in Industrial Engineering and Management – PRODEGI
Faculty of Engineering of University of Porto – FEUP

Thank you for considering taking part in this research. If you have any questions, please ask the moderator of the focus group before you decide whether to take part. You will be given a copy of this consent form to keep and refer to at any time.

	Please tick (✓) if you agree
I confirm that I have read and understood the information sheet provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my care or legal rights being affected.	
I know my personal information will be kept private and that quotations and information will not be attributed to me in the study.	
I agree that my name can be included in the list of people who were involved in the study.	
I agree to the interview being audio recorded.	
I understand that if I withdraw from the study the data collected up to that point will be destroyed.	
I agree to take part in the study.	

Please note that you can still take part in the focus group if you do not tick agreement for some of the above statement, as long as you confirm agreement to take part in the study. Your choices for other statements will be accommodated.

Name of participant _____

Signed_____ Date _____

Name of focus group moderator: Ariane Rodrigues Pereira. Signed Date: 06/06/2017
For more information, contact: Ariane R. Pereira, arianerp@gmail.com 910 720 202